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EXCELENCIA SEVERO OCHOA

Decadal Climate Prediction with EC - Earth

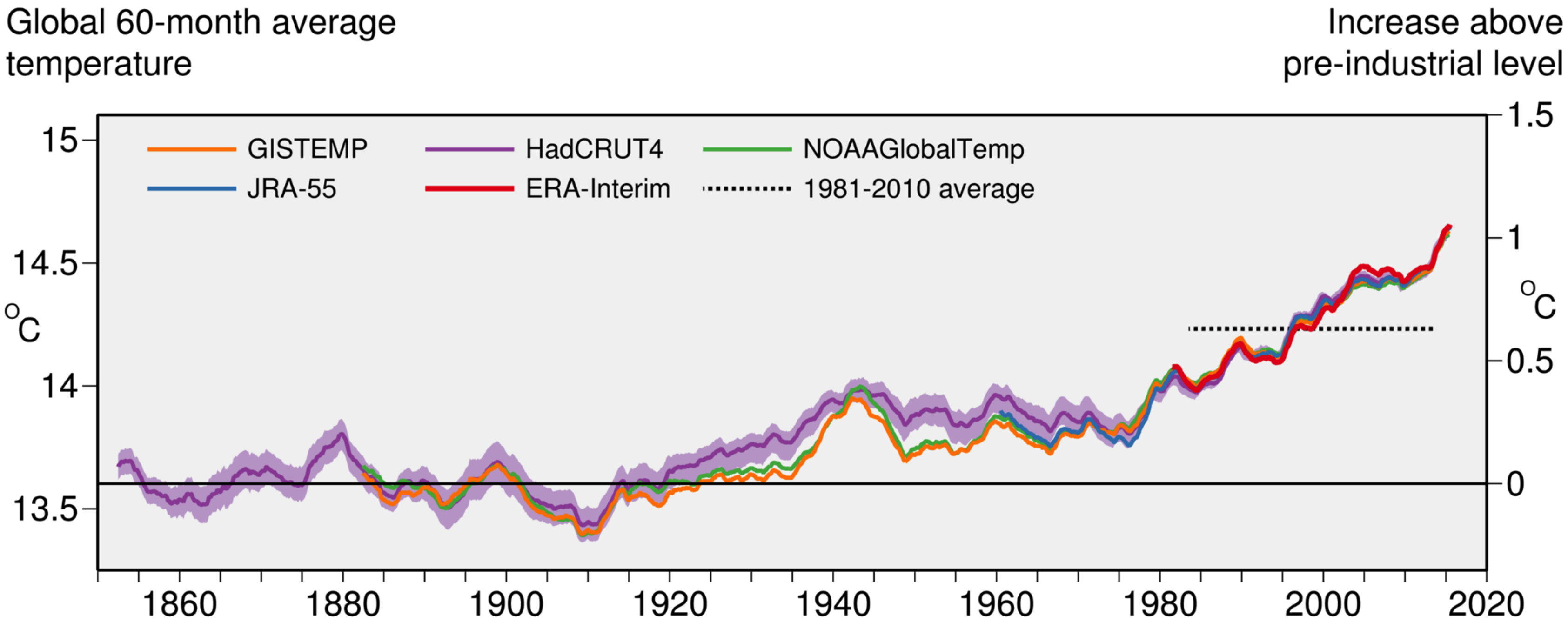
Simon Wild

R Bilbao, J Acosta, A Amaral, LP Caron,
R Cruz-García, F Doblas-Reyes, M Donat,
P Ortega, Y Ruprich-Robert, V Sicardi,
B Solaraju-Murali, E Tourigny, D Verfaillie

17/01/2020

OCP Seminar - LDEO Columbia University

Climate is changing…

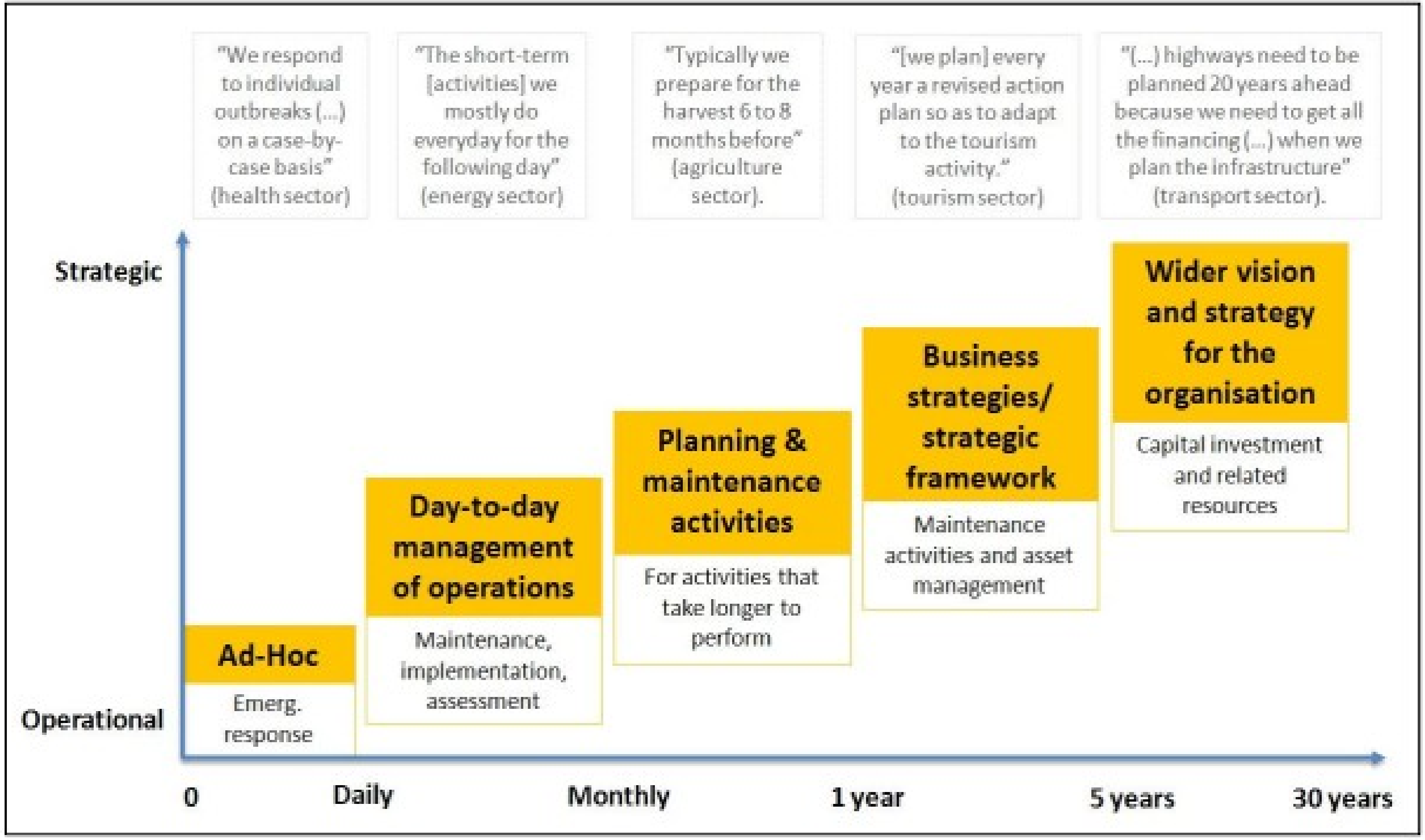


…we need to prepare for climate conditions to come (besides mitigating the worst of course!)

User Perspective

Mid-term planning (1-5 yr): business strategies often linked to annual capital investment plans

Long-term planning (5-30 yr): wider vision and strategy, and associated resources and capital investment



Dessai and Bruno-Soares (2013)

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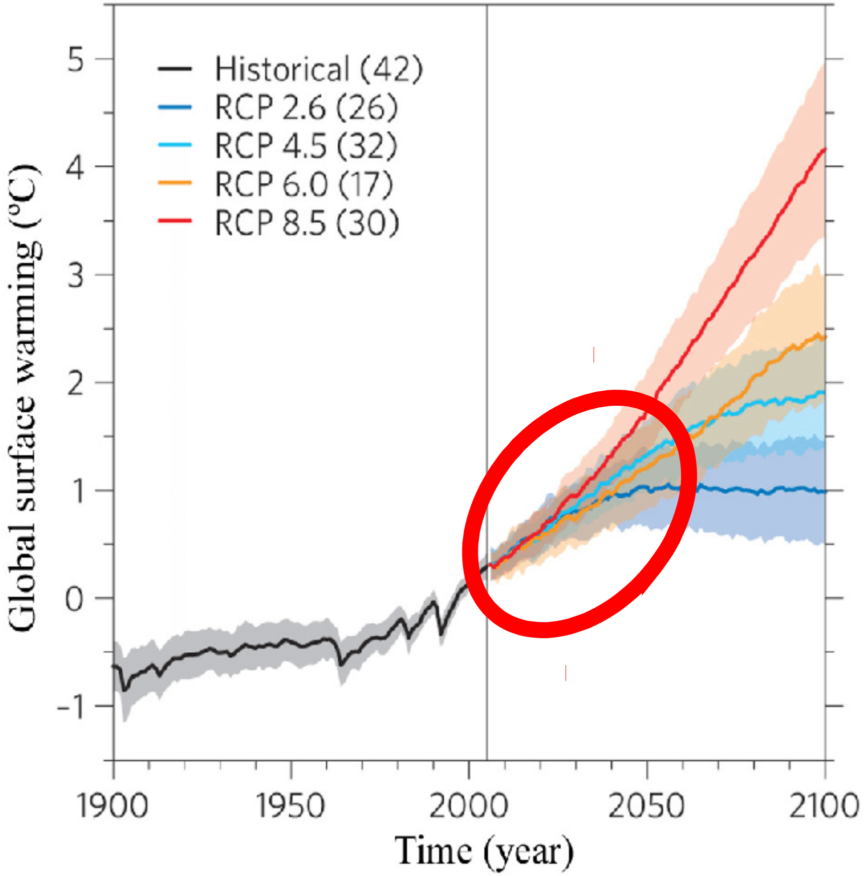
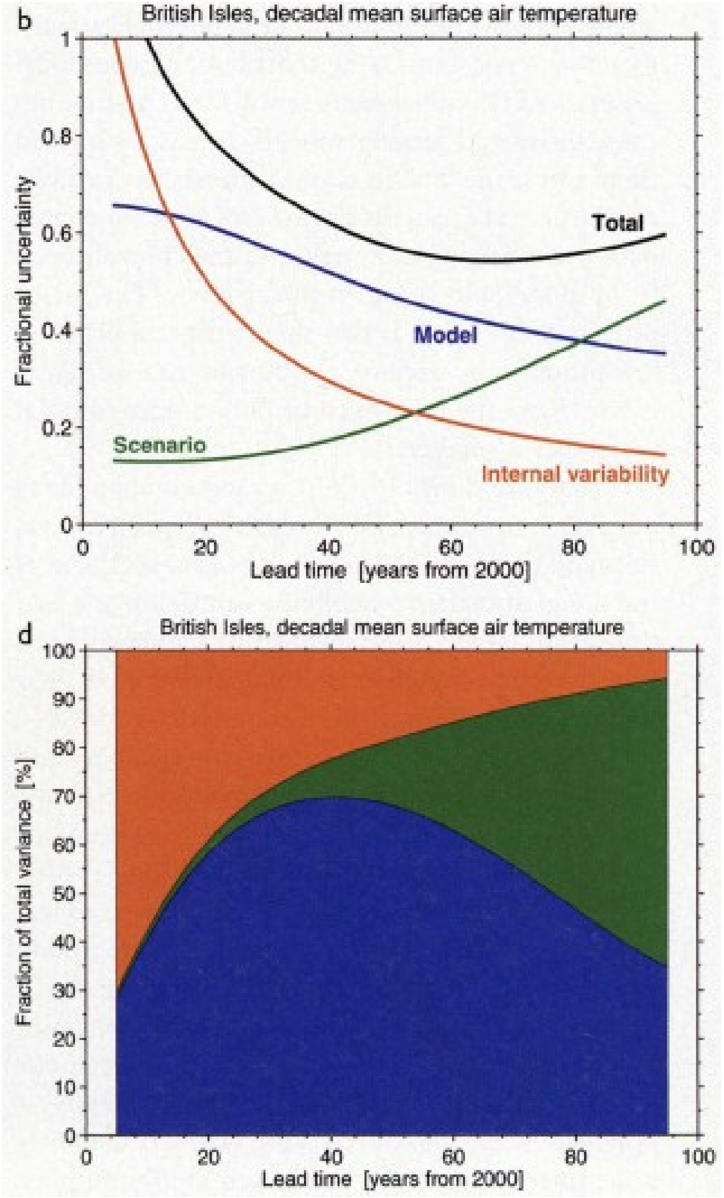
Future Climate Simulations

Global temperature changes (CMIP5)



Knutti and Sedlácek (2013)

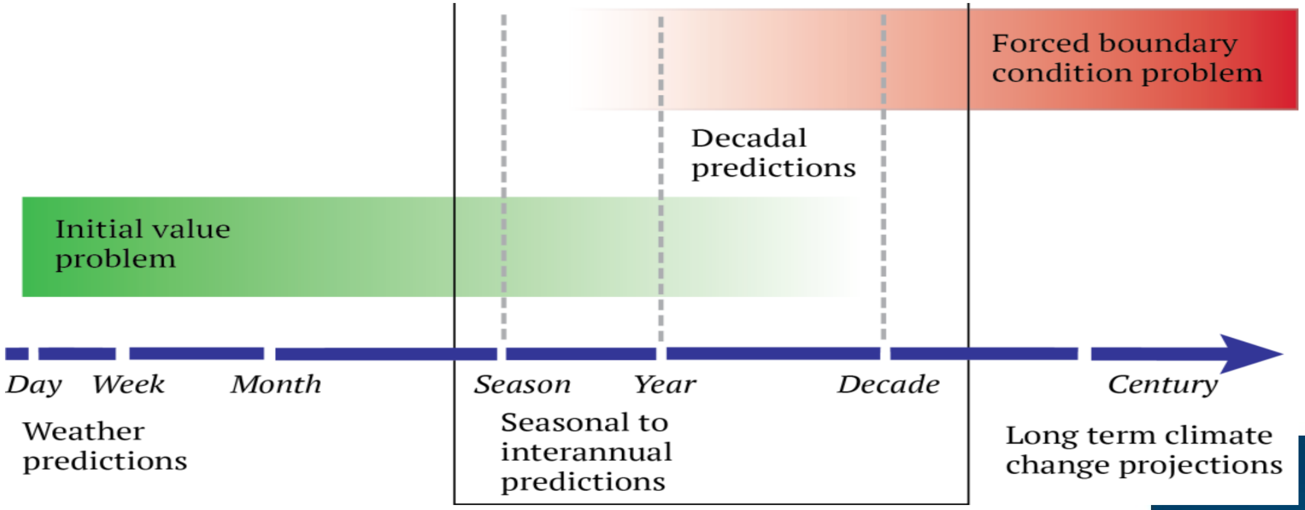


Sources of uncertainty include internal variability, model differences and scenario spread

Internal variability dominates during first decades

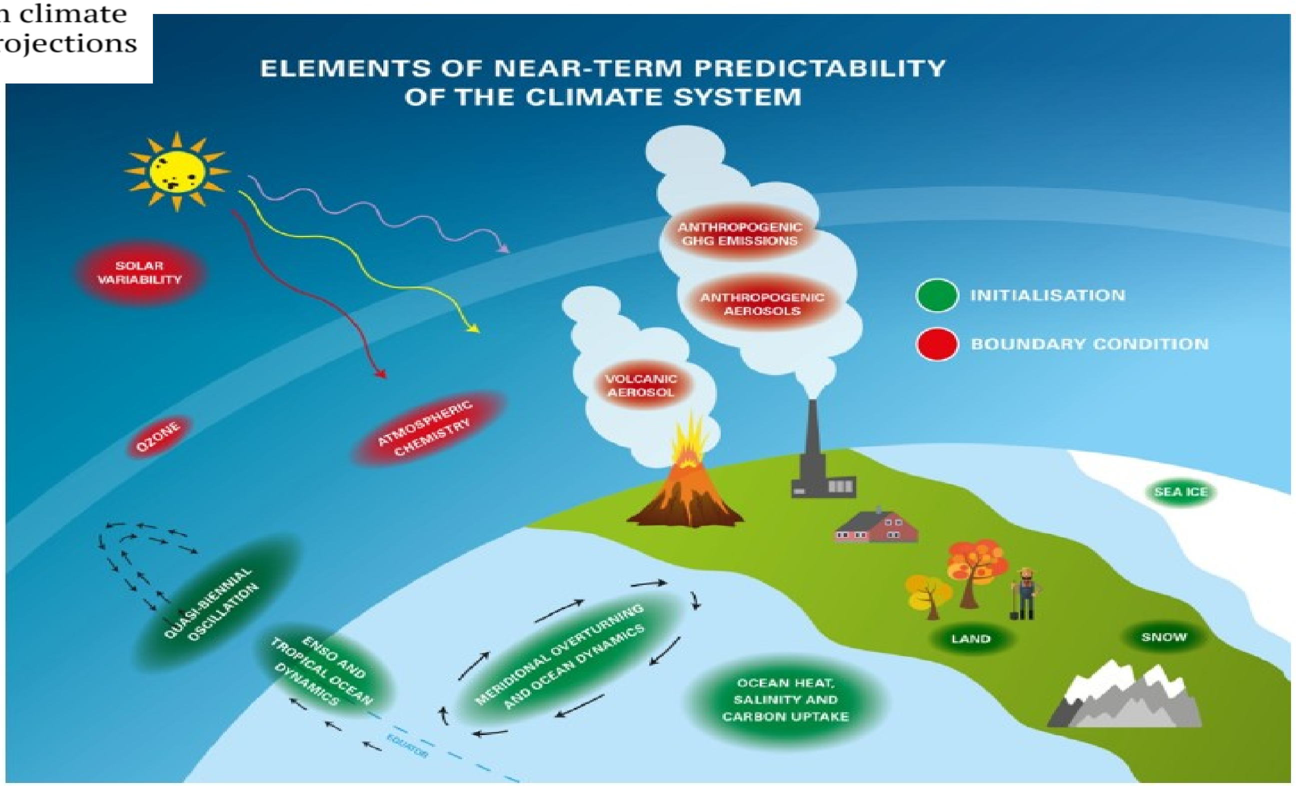
Hawkins & Sutton (2009)

Near Term Climate Prediction



Meehl et al. 2009

Kushnir et al. 2018



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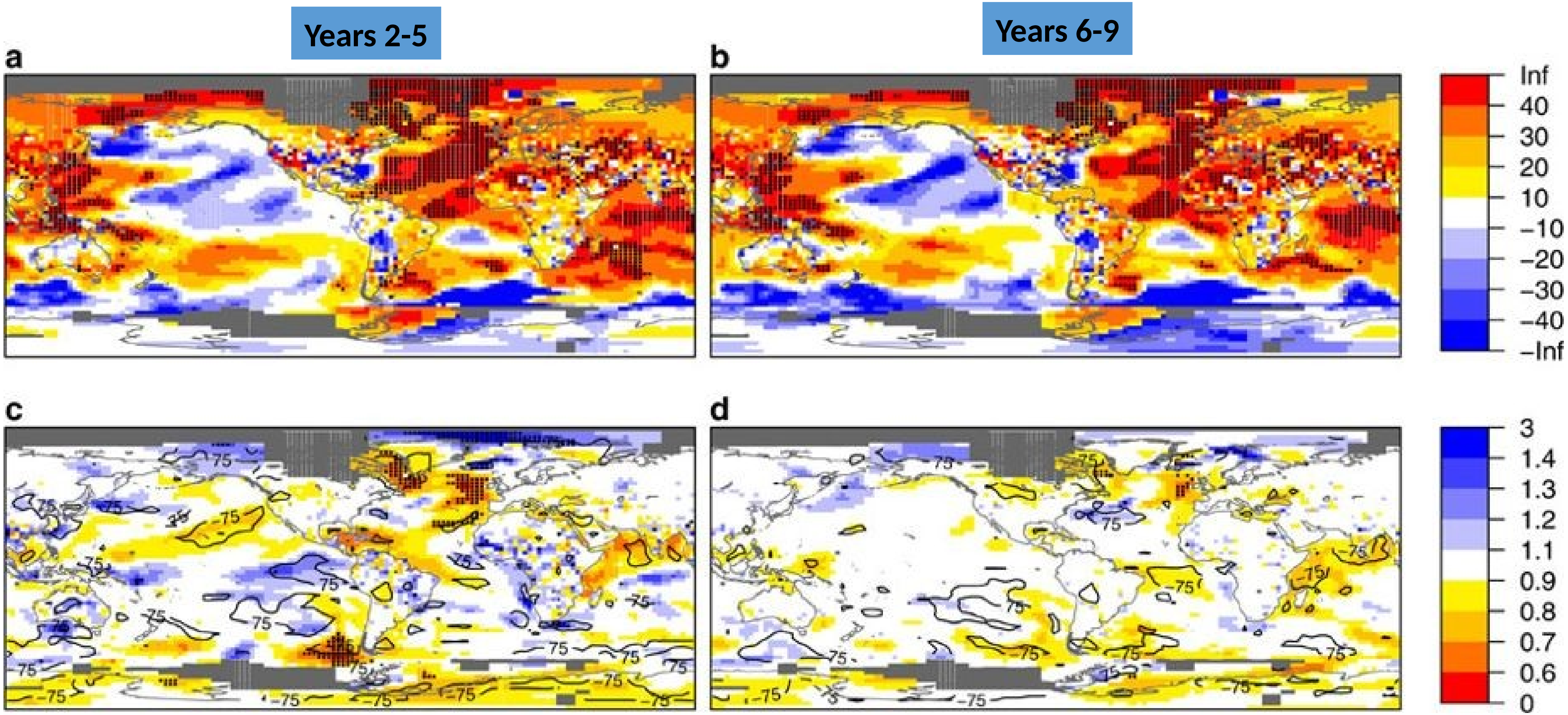
Added value from initialization? - SST

e.g. near-surface temperature in CMIP5 (RMSSS)



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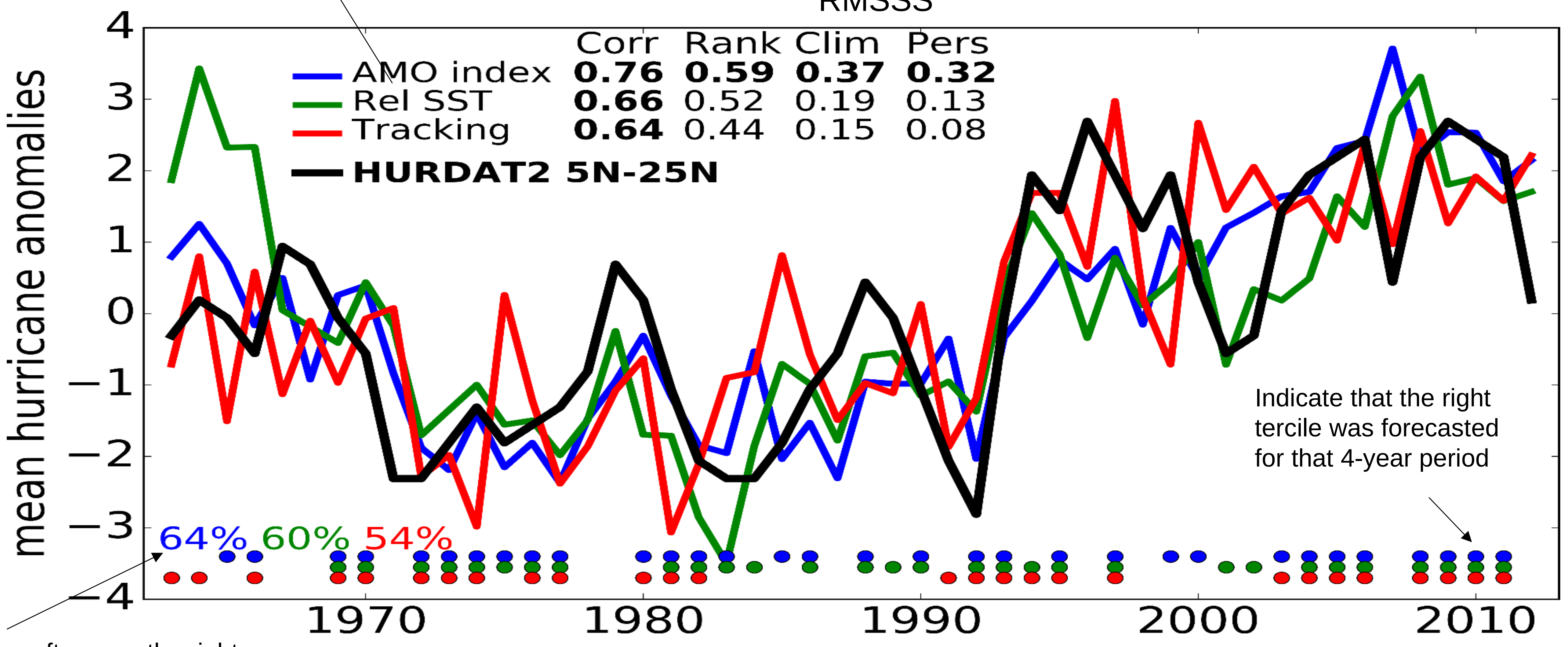
Doblas-Reyes et al. 2013

Applications: tropical cyclones

Years 2-5

3 different techniques



Indicate that the right tercile was forecasted for that 4-year period

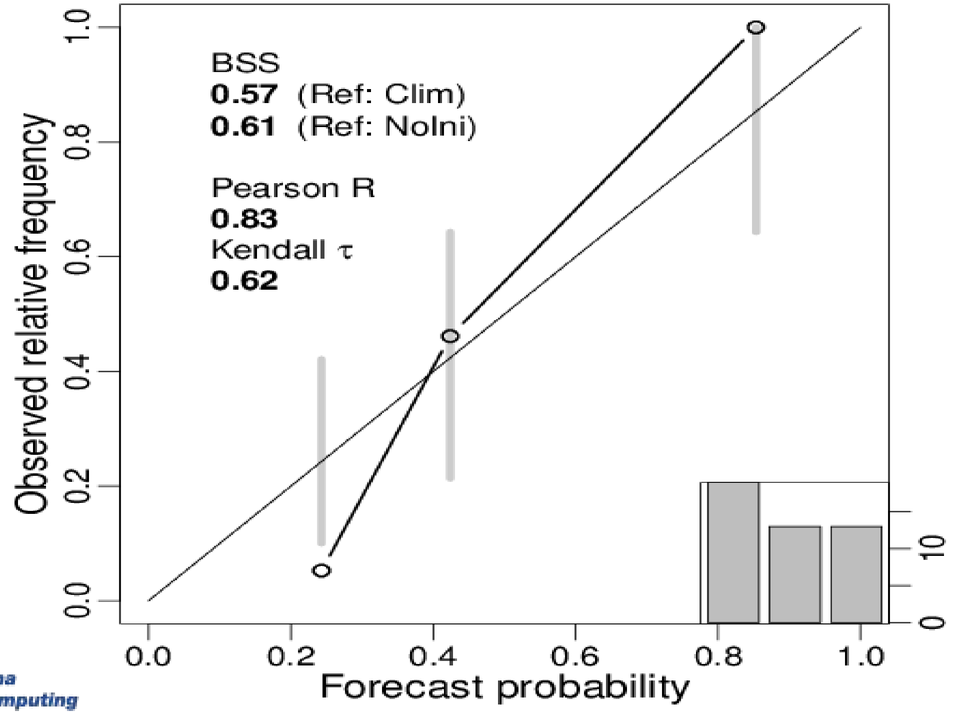
How often was the right tercile forecasted?

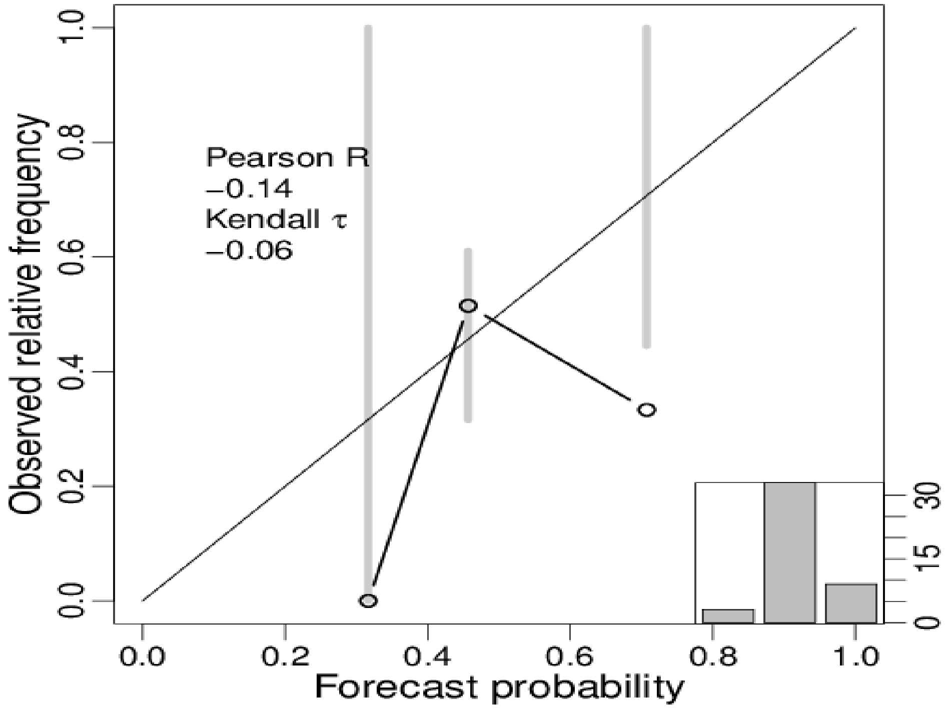
Caron et al. 2018

Applications: tropical cyclones

Reliability diagrams of (left) initialised and (right) uninitialised multi-model simulations for basin-wide **accumulated cyclone energy** (ACE). The results are for 2-9 year averages above the climatological median over 1961-2009. Statistically significant values are in bold.

Some of the added value of the predictions is their better management of uncertainty, which leads to increased **credibility**.





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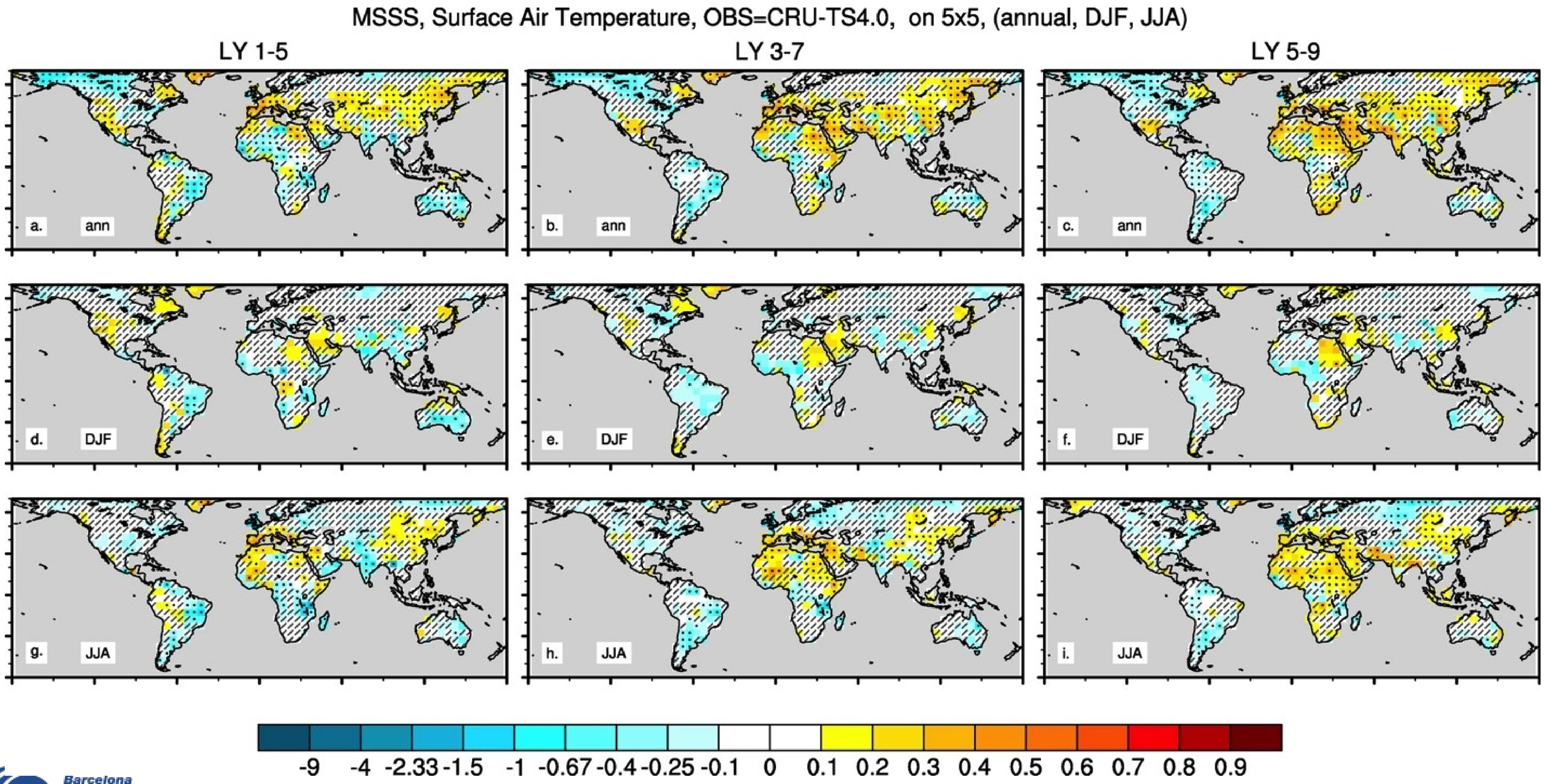
Caron et al. 2015

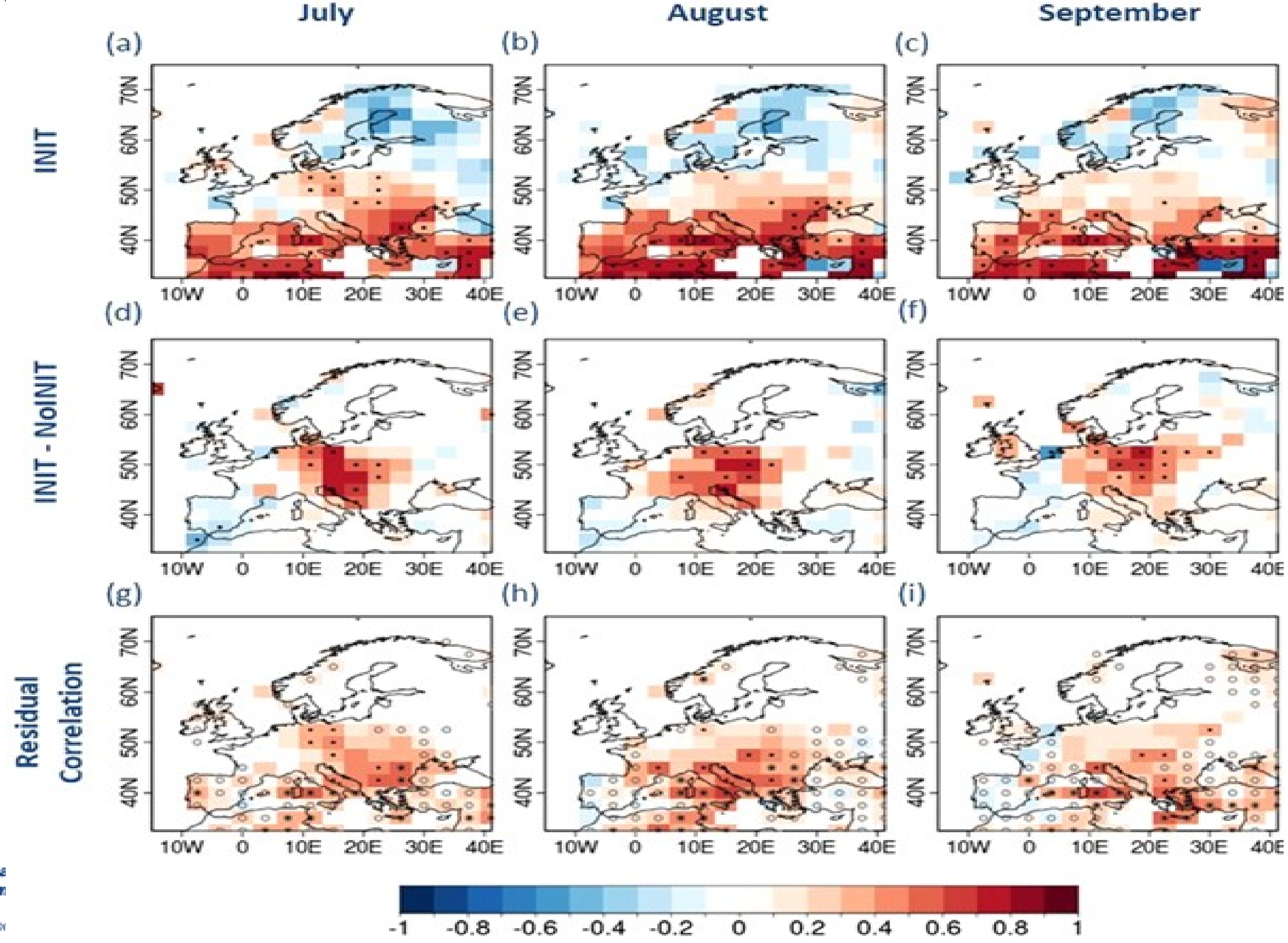
Added value from initialization? – Over land



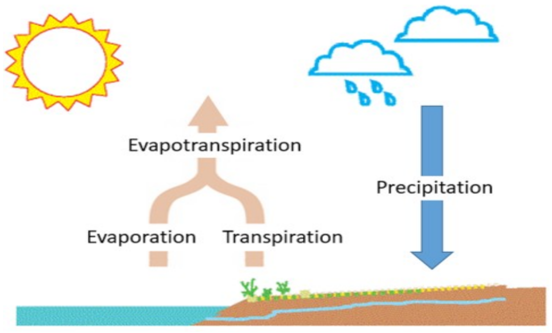
Yeager et al. 2018

Applications: droughts

Skilful predictions of **drought indicators** (e.g. SPEI6) for the boreal summer averaged over forecast years 2 to 5



INIT: Initialized decadal prediction
NoINIT: Non initialized climate projection



Solaraju-Murali et al 2019

Real-time decadal prediction

The multi-model real-time decadal prediction exchange is a research exercise that guarantees equal ownership to the contributors.

BSC is one of the four centers recognized as global producers of decadal climate predictions by WMO-Commission of Climatology.

Multi-model decadal forecast exchange

The Met Office coordinates an informal exchange of near-real time decadal predictions. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic.

The contributing prediction systems are a mixture of dynamical and statistical methods. The prediction from each institute is shown below, alongside an average of all the models. When possible, observations for the period of the forecast are also shown. Currently three variables are included: surface air temperature, sea-level pressure and precipitation. These are shown as differences from the 1971-2000 baseline. More diagnostics, including ocean variables are planned for the future. Please use the drop-down menus below to explore the data collected to date.

This work is supported by the European Commission SPECS project.

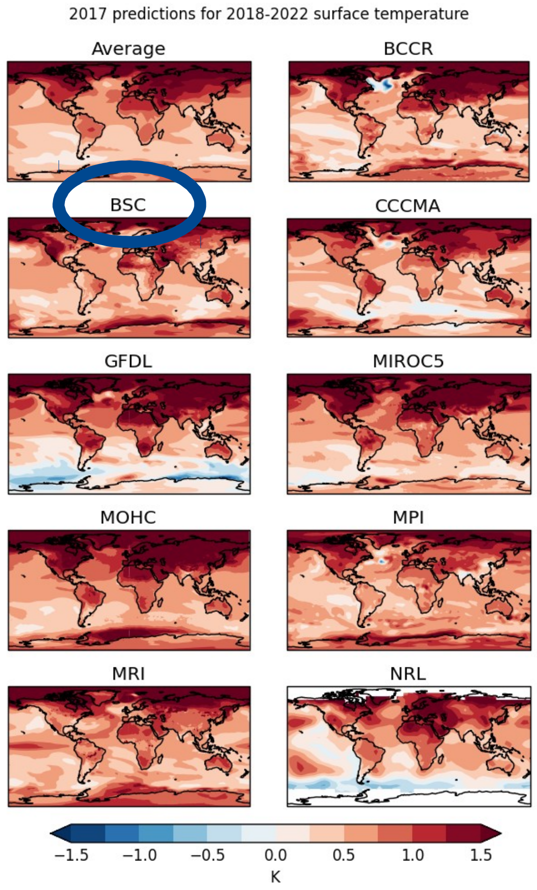
SPECS

Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

To learn more about decadal forecasts at the Met Office, see our current decadal forecast.

Images last updated 2014-06-25

Issued	Period	Element
2013	year 1	surface air temperature



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World Meteorological Organization

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Decadal Prediction with EC - Earth as part of CMIP6 / DCPP

DCPP

World Climate Research Programme

WMO

ICSU

The Decadal Climate Prediction Project (DCPP)

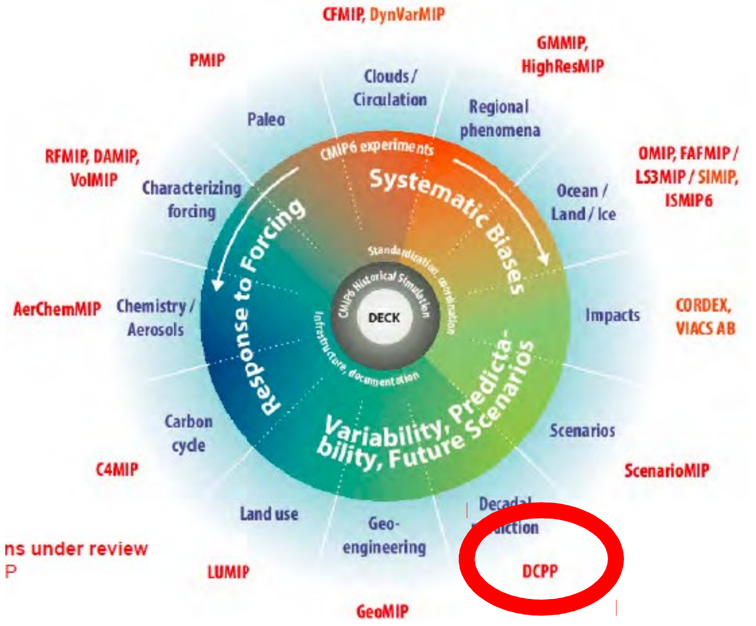
The term ""decadal prediction"" encompasses predictions on annual, multi-annual to decadal timescales. The possibility of making skilful forecasts on these timescales and the ability to do so is investigated by means of predictability studies and retrospective predictions (hindcasts) made using the current generation of climate models and by empirical methods. Skilful decadal prediction of relevant climate parameters is a Key Deliverable of the WCRP's Grand Challenge of Near-term Climate Prediction

The DCPP envisions three components:

A ○ ***Hindcasts***: the design and organization of a coordinated decadal prediction (hindcast) component of CMIP6 in conjunction with the seasonal prediction and climate modelling communities

B ○ ***Forecasts***: the ongoing production of experimental quasi-operational decadal climate predictions in support of multi-model annual to decadal forecasting and the application of the forecasts

C ○ ***Predictability, mechanisms and case studies:*** the organization and coordination of decadal climate predictability studies and of case studies of particular climate shifts and variations including the study of the mechanisms that determine these behaviours



DCPP A Protocol

- yearly initialized experiments
- 1960-2017
- 10 members
- 10 forecast years

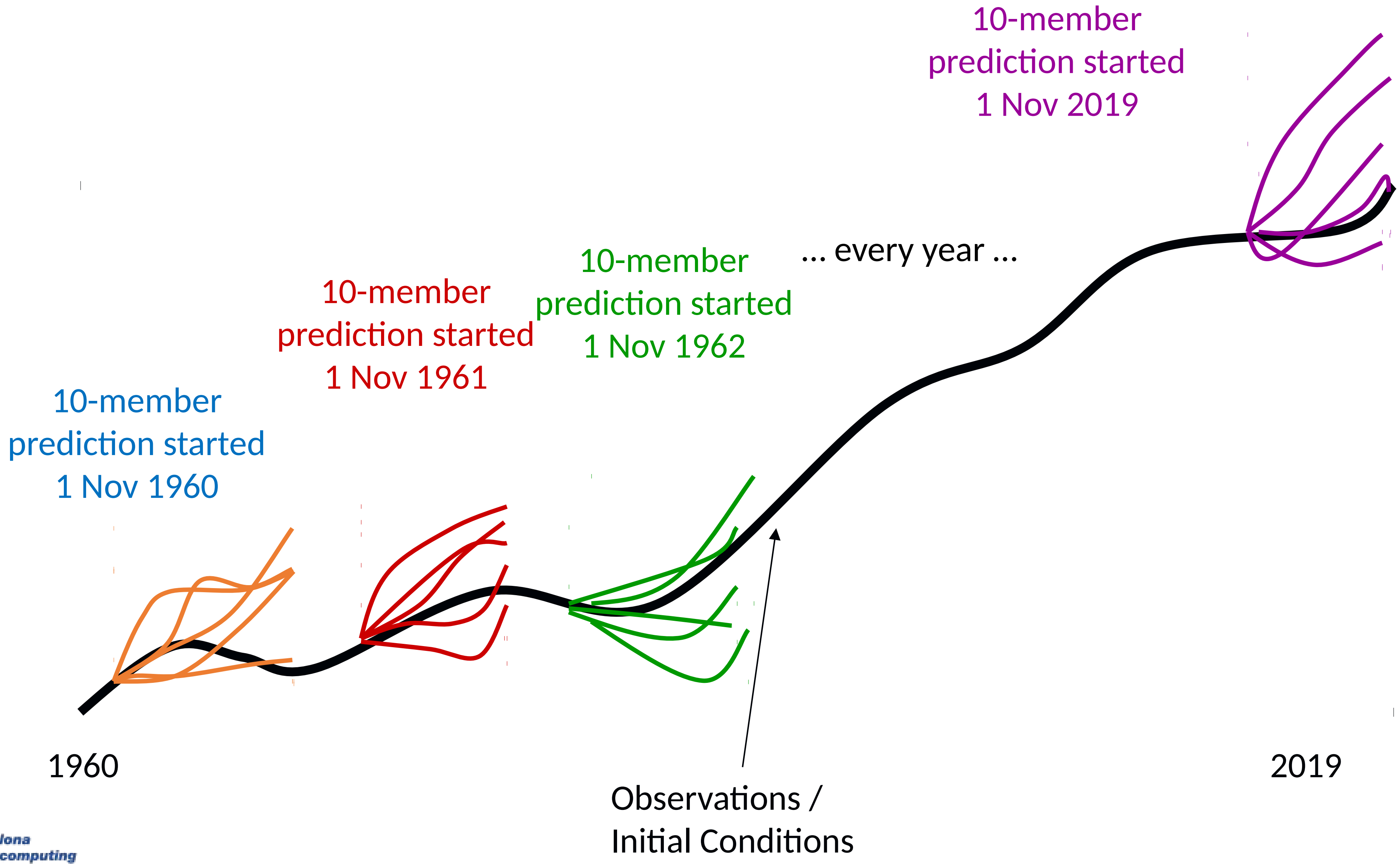
DCPP

Group/Model	Institution	Country	Component A	B	C
EC-Earth	BSC/SMHI	Spain/Sweden	Y/M	Y/M	M/M
GFDL	NOAA	USA	Y	Y	M
FIO-ESM	FIO	China	Y	Y	M
NUIST-CSM	IPRC	USA/China	Y	Y	N
BCC	BCC	China	Y	N	N
CAS-ESM	CAS	China	M	M	M
MIROC	JAMEST/JMA	Japan	Y	y	Y
Can-ESM5	CCCma	Canada	Y	Y	M
CNRM-CERFACS	CNRS	France	M	M	Y
MetOffice	MetOffice	UK	Y	Y	Y
Ureading/Stat	UReading	UK	Y	Y	Y
IPSL	LOCEAN	France	Y	N	Y
NERCS/NorCPS	GRI	Norway	Y	Y	Y
CMCC	CMCC	Italy	M	M	Y
MPG	MPI	Germany	Y	Y	Y
NCAR/CESM	NCAR	USA	Y	Y	Y
BESM	INPE	Brazil	Y	M	M
FGOALS	IAP	China	Y	M	Y
INM	RAS	Russia	Y	N	Y

20 Groups

- 13 Countries
- Component A (hindcasts)
  - 16 Yes, 4 Maybe
- Component B (forecasts)
  - 11 Yes, 6 Maybe, 3 No
- Component C (mechanisms)
  - 11 Yes, 7 Maybe, 2 No

Decadal Hindcasts



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CMIP6 Model and Full-Field Initialization

Decadal Hindcasts (DCPP-A)
- yearly start dates
- starting 1st Nov
- 1960-2018
- 10 members

EC-Earth 3.3
- Atmosphere: IFS, T255L91
- Ocean: NEMO, ORCA1L75
- Sea ice: LIM 3
- + OASIS coupler

ATM:
Interpolated to model grid with OpenIFS

LAND:
Offline land-surface simulation with near-surface meteorology and corrected fluxes from ERA-Interim

Atmosphere reanalysis (**ERA 40 + Interim**)

Land reanalysis (**ERA-Land**)

Ocean reanalysis (**ORAS4**)

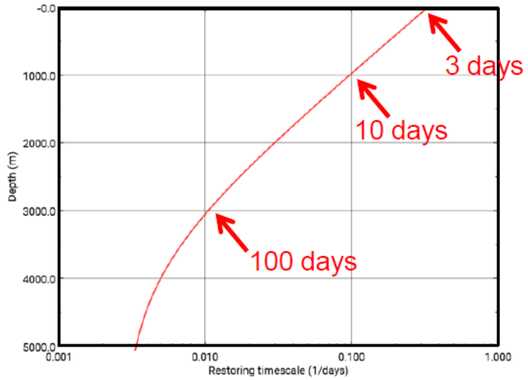
Sea Ice reanalysis

Default surface restoring coefficients

γ_T = **-40W/m²/K**

γ_S = **-150 kg/m2/s/psu**

Default 3D restoring timescales



OCE+ SI:
Historical reconstruction with NEMO-LIM stand alone, forced with DFS/ERA-Interim fluxes, and nudged globally towards 3D T and S from ORAS4

Following Guemas et al. 2014

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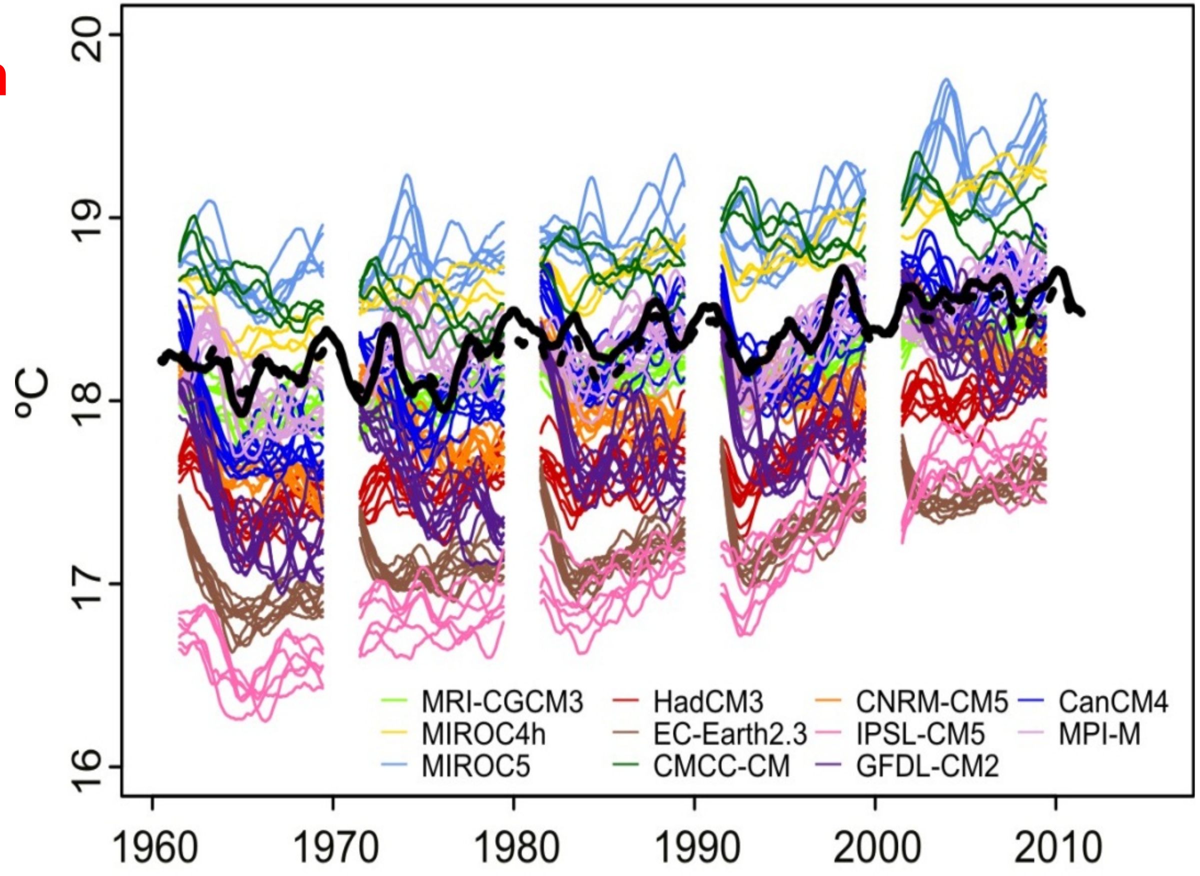
Issues with initializing decadal predictions - shocks and drift

Global mean near-surface air temperature over the ocean (one-year running mean applied) from CMIP5 hindcasts. Each system is shown with a different colour. NCEP and ERA40/Int used as reference.

Shock and drift is the norm



IPCC AR5 WGI (2013)

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Surface Temperature – Year 1

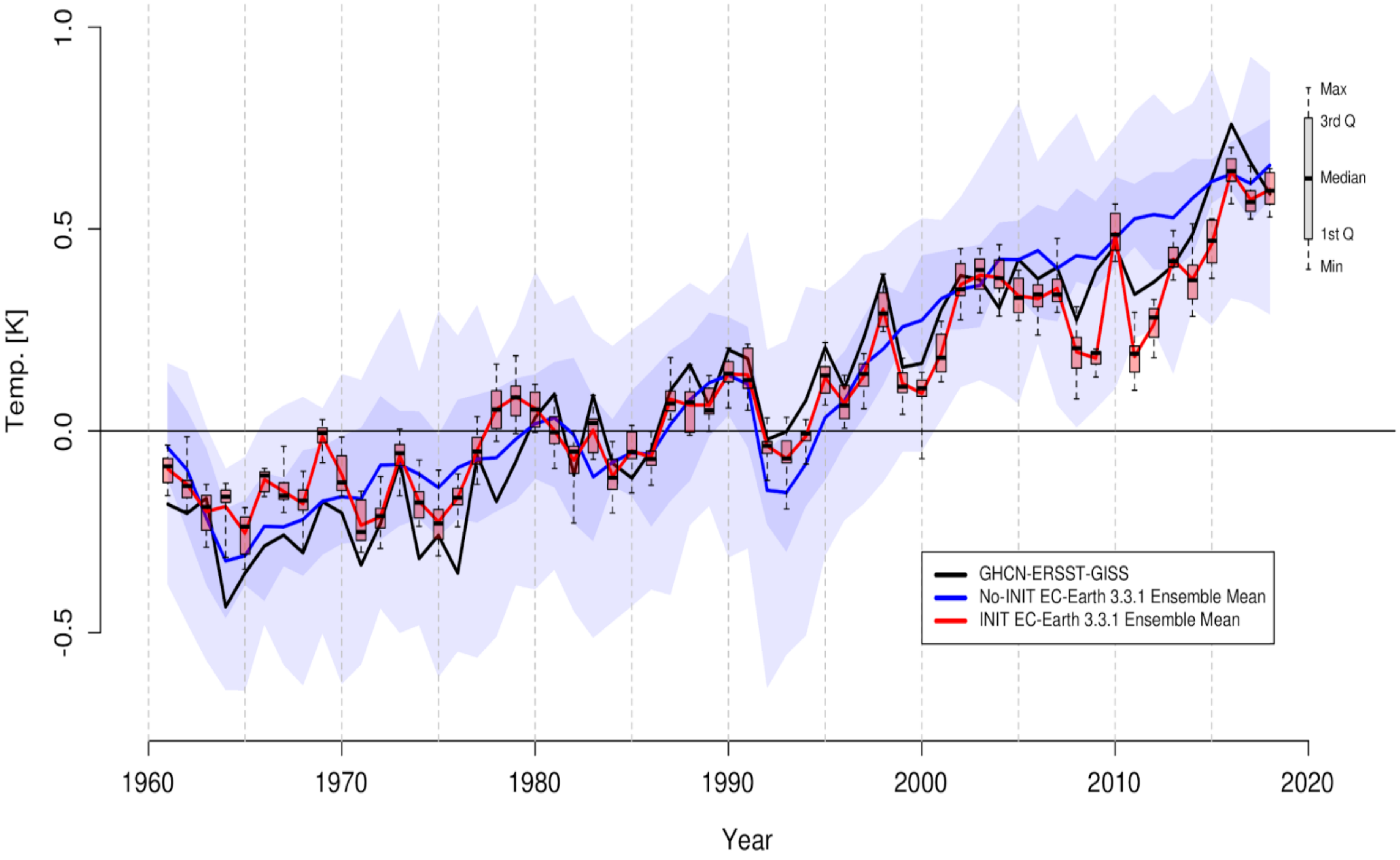
Combined
surface temperature:

- **2m over land**
- **SST over ocean**

INIT: 10 members
No-Init: 15 members

Hatching: significant (95%) correlation / difference

Year 1= Month 3 - 14



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Skill Assessment – Surface Temperature

Anomaly Correlation Coefficient

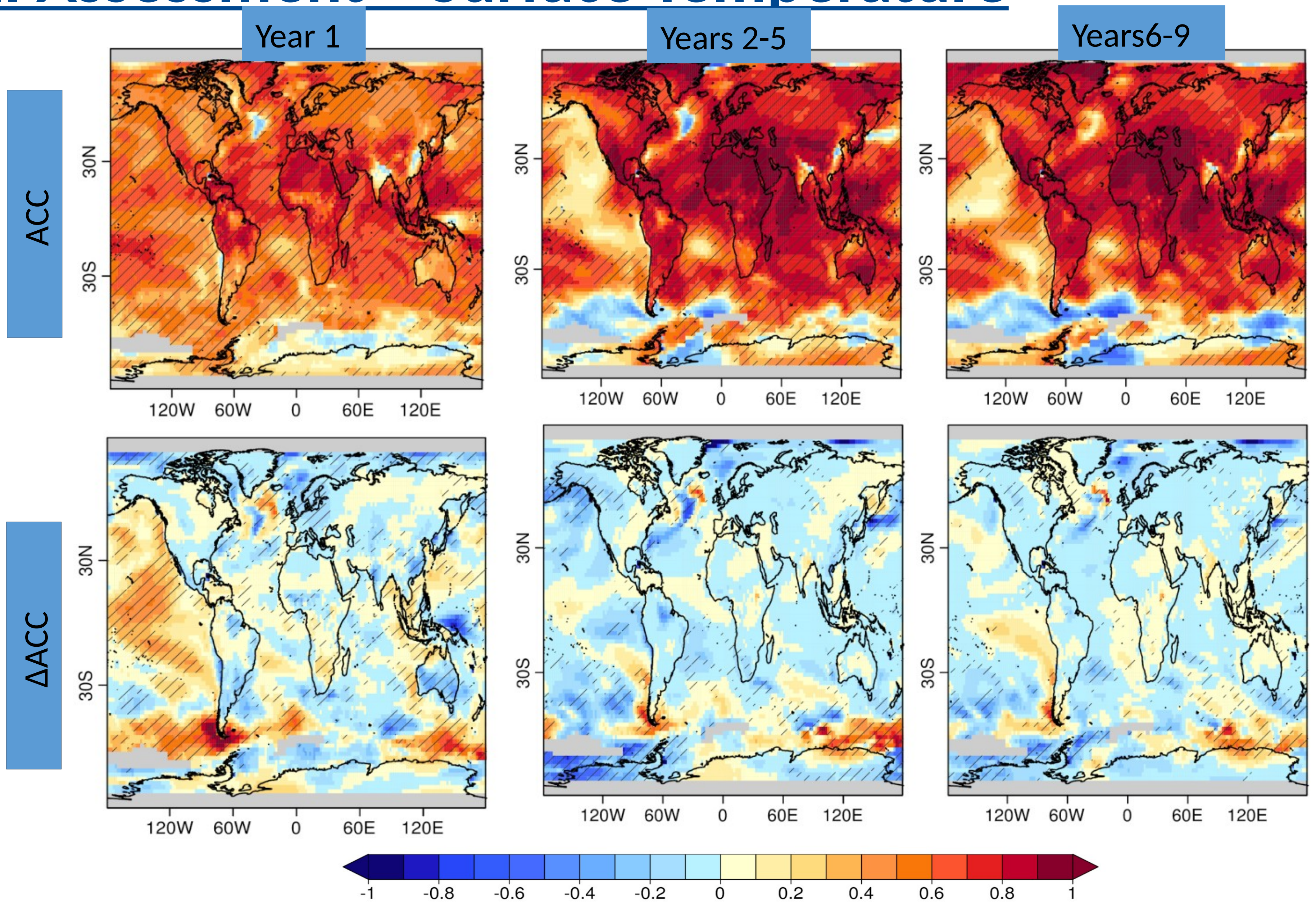
Combined surface temperature:

- **2m over land**
- **SST over ocean**

INIT: 10 members
No-Init: 15 members

Hatching: significant (95%) correlation / difference

Year 1= Month 3 - 14



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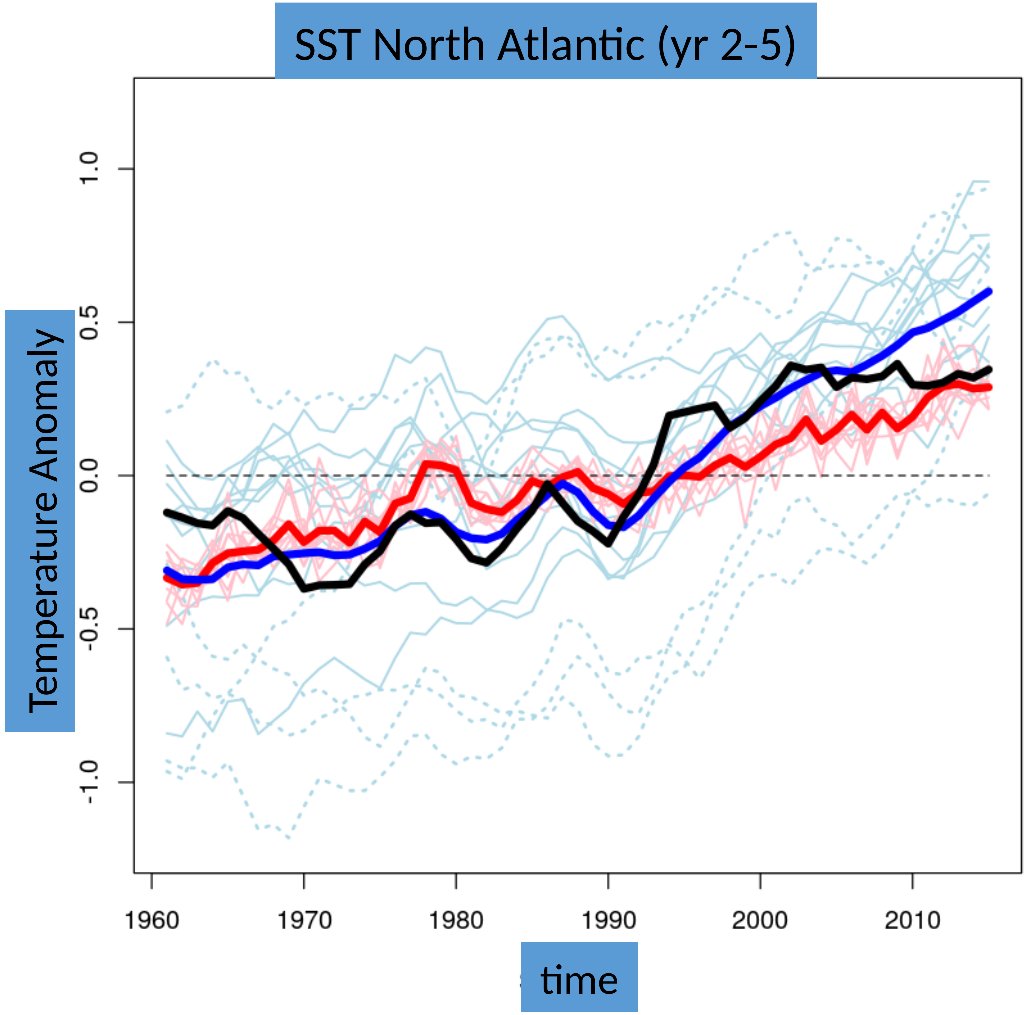
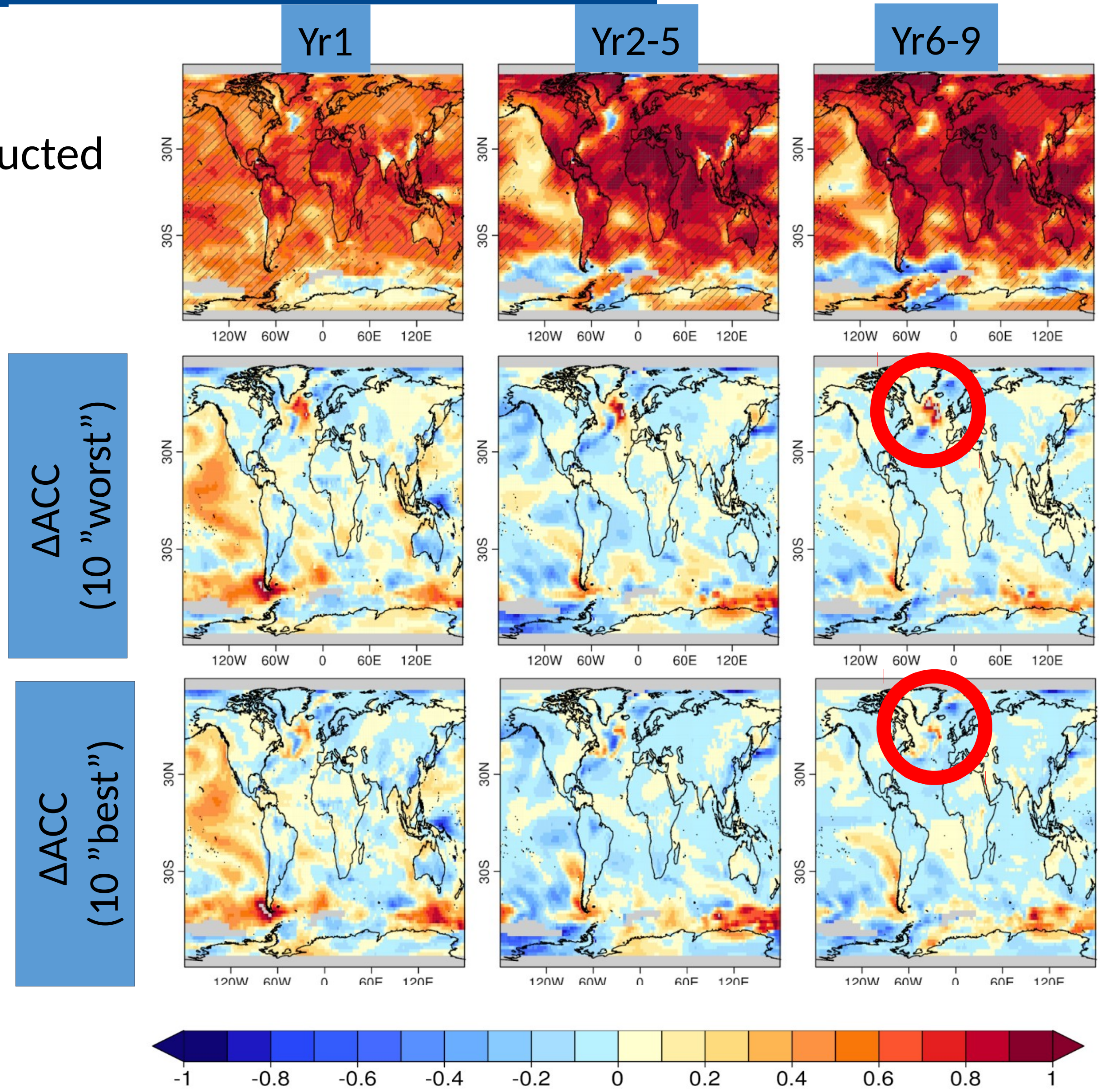
Added value depends on reference

Un-initialized runs show vide range of behavior;

skill estimates depend on how the ensemble is constructed

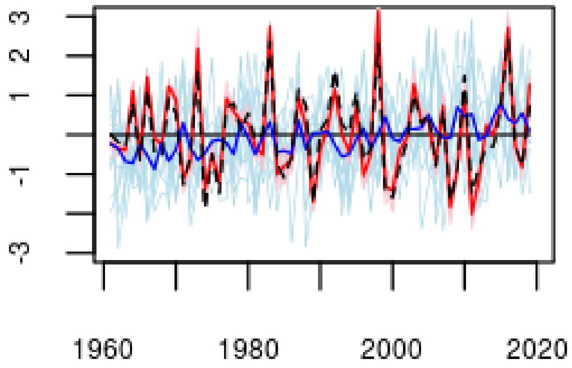




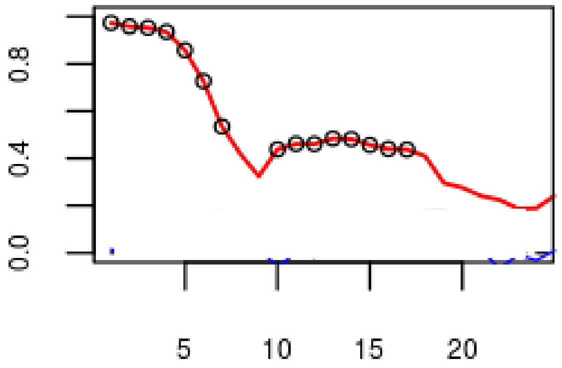
Skill Assessment – Ocean Indices

ACC: Anomaly Correlation Coefficient
MSSS: Mean Squared (Error) Skill Score

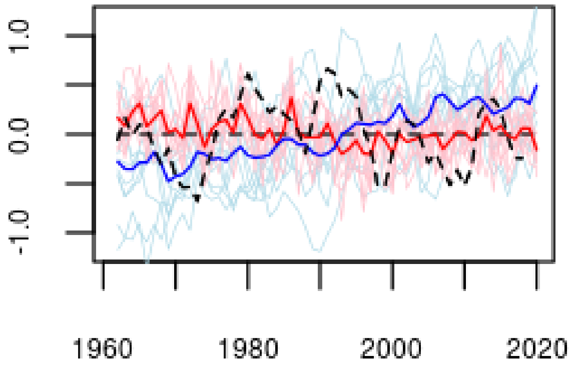
Nino 3.4, 1st DJF



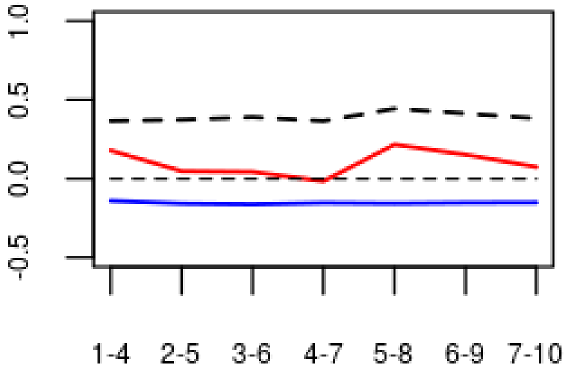
Nino 3.4, ACC



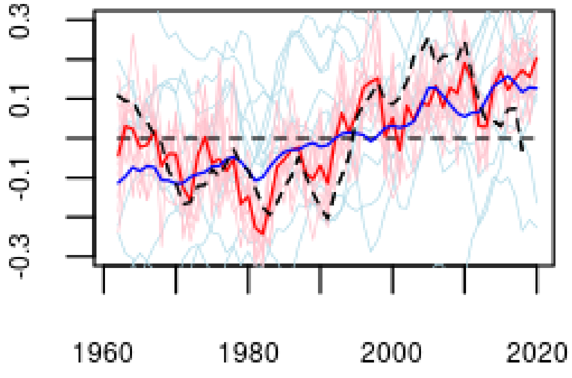
IPO, Years 2-5



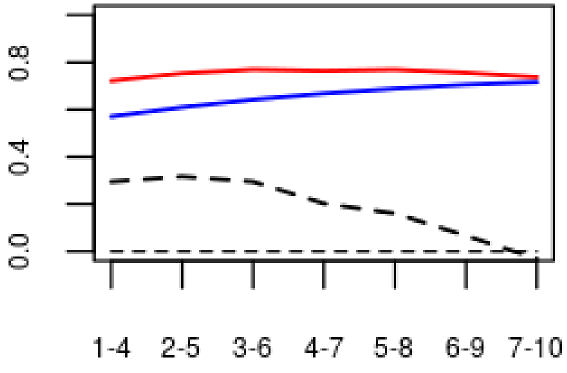
IPO, ACC and MSSS



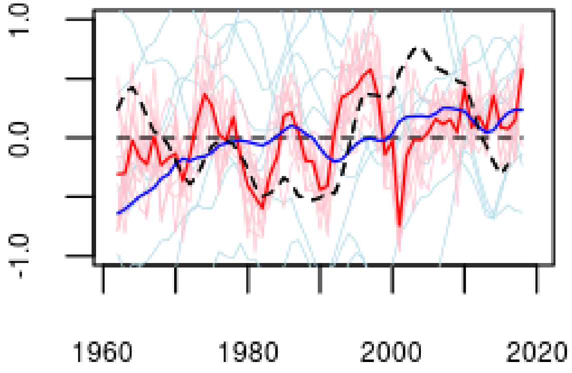
AMV, Years 2-5



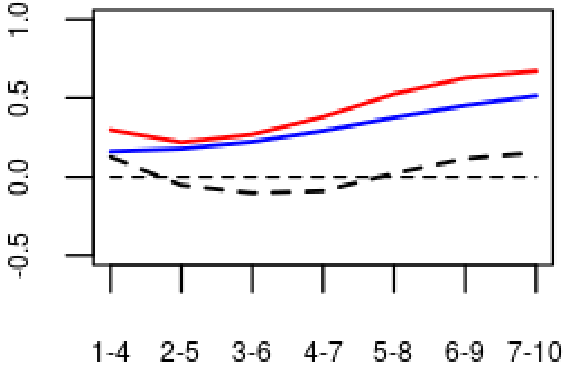
AMV, ACC and MSSS



SPG OHC300, Years 2-5



SPG OHC300, ACC and MSSS



No-INIT EC-Earth 3.3.1 Ensemble Mean
INIT EC-Earth 3.3.1 Ensemble Mean
HadISST

AMV: Atlantic Multidecadal Variability
IPO: Interdecadal Pacific Oscillation
SPG OHC: North Atlantic Subpolar Gyre Ocean Heat Content

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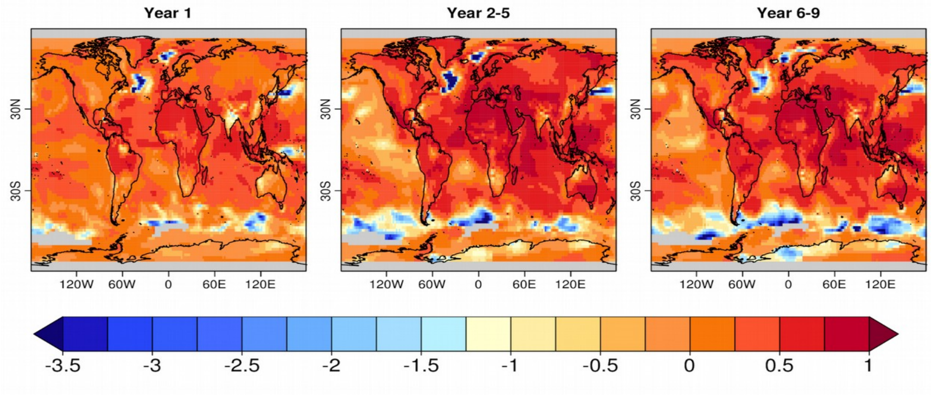
Conditional Bias

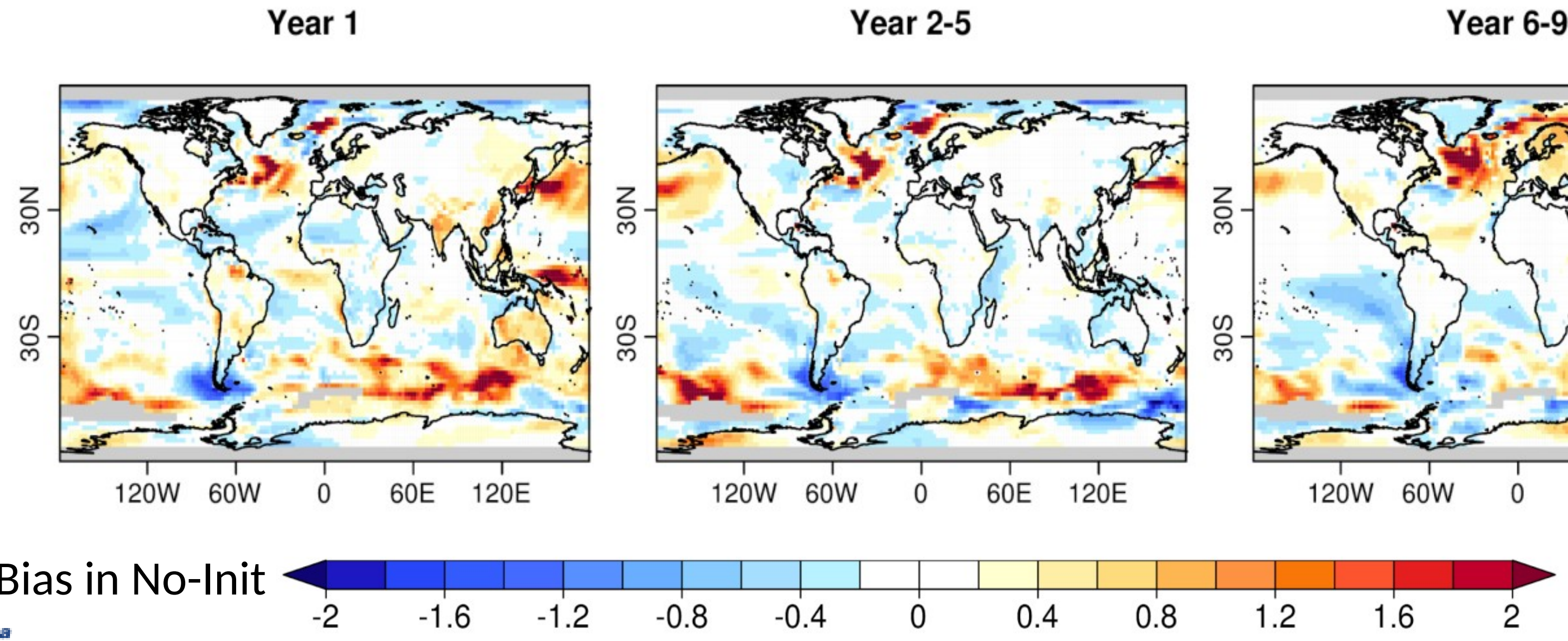
Forecast accuracy: Mean Squared (error) Skill Score (MSSS)

$$MSSS(H, \bar{O}, O) = r_{HO}^2 - \left[r_{HO} - \frac{S_H}{S_O}\right]^2 - \left[\frac{\bar{H} - \bar{O}}{S_O}\right]^2$$

r_{HO}: sample correlation between the hindcasts and the observations
$S_H{}^2$; $S_O{}^2$: the sample variances of the ensemble mean hindcasts and observations,
$\bar{O} = \sum_{j=1}^{n} O_j$: climatological forecast (where *Oj* represents the observations, or perfect-model reference respectively, over *j* = 1,…,*n* start times), $\bar{H}$ the mean hindcast



Difference Init minus No-Init of conditional bias (absolute values)



Greater Cond. Bias in No-Init

Greater Cond. Bias in Init

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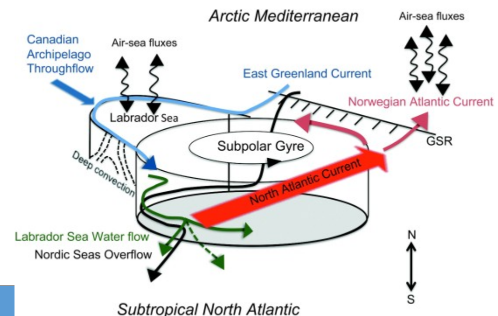
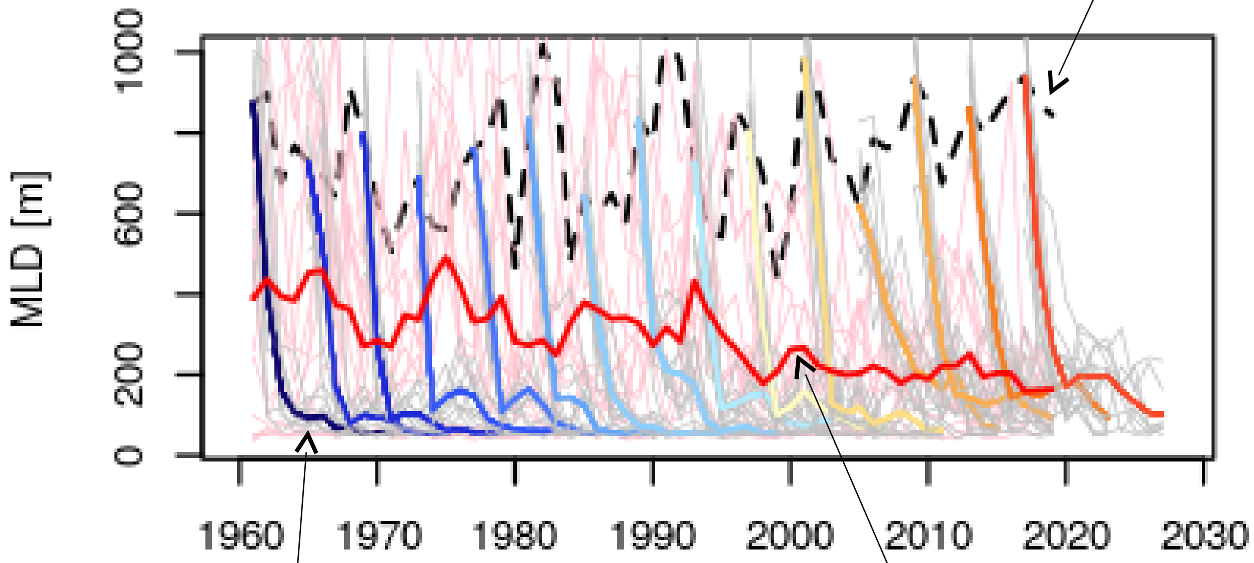
Model Drift in North Atlantic

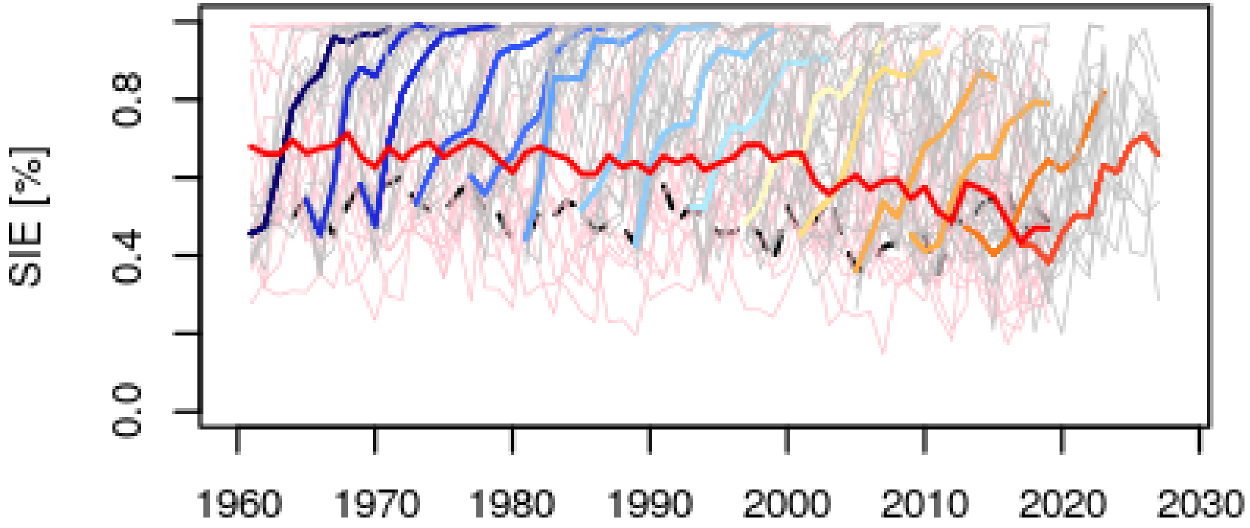


Mixed Layer Depth,
Labrador Sea, March-April

Initial state
(black dotted line)



Sea Ice Extent,
Labrador Sea, March-April



INIT Ensemble Mean
every 4th start date
(dark blue to dark red lines)

NO-INIT
(red line)

INIT does not drift towards NO-INIT

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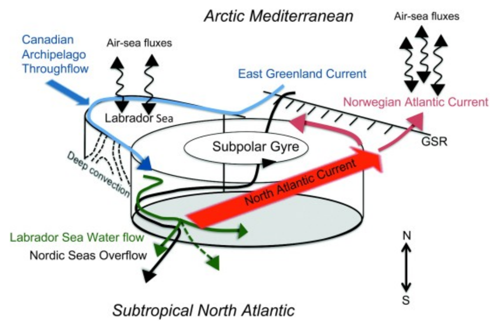
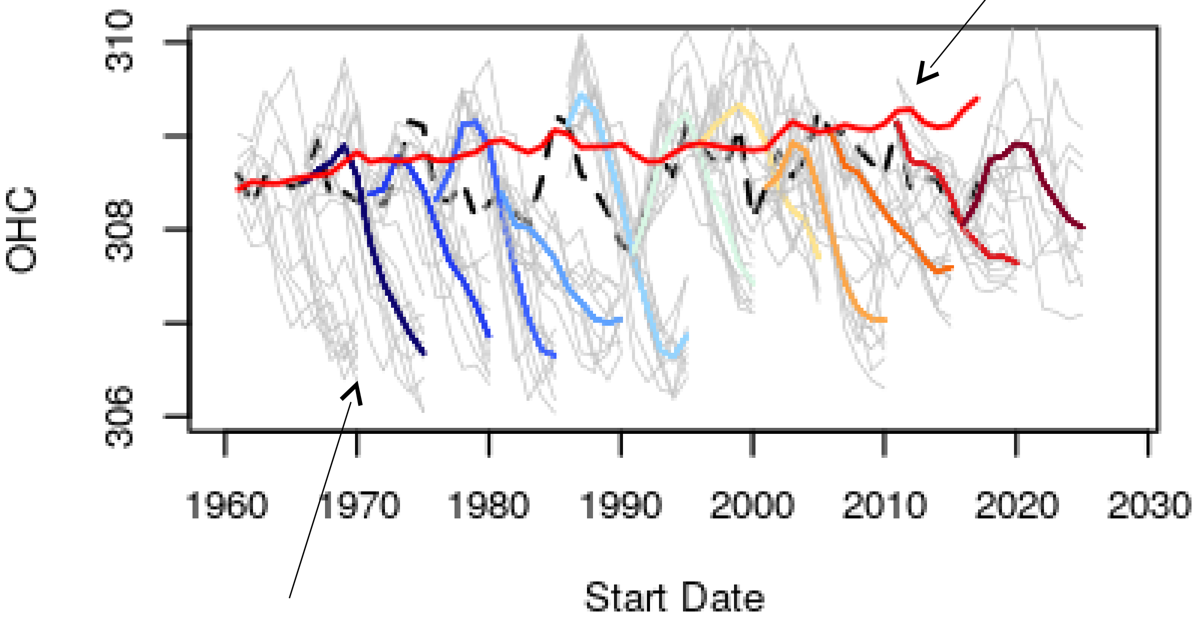
Model Drift in the North Atlantic



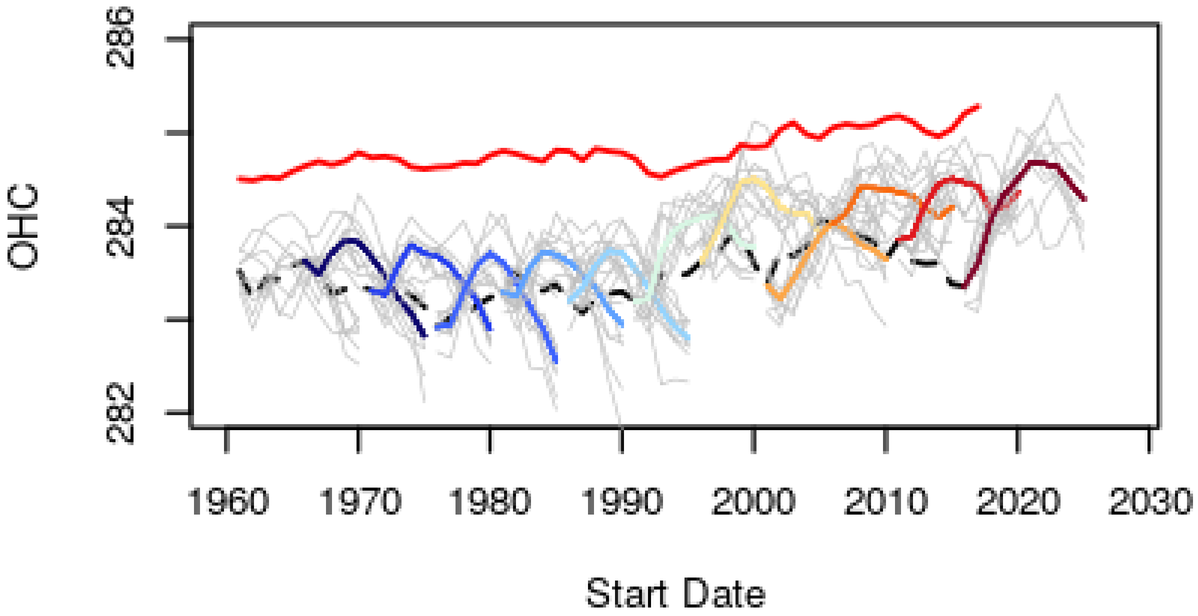
Western Subpolar Gyre,
OHC 300, March-April

NO-INIT
(red line)



INIT Ensemble Mean
(dark blue to dark red lines)

Eastern Subpolar Gyre,
OHC 300, March-April



- Initial tendency to a warmer state.
- Tendency is disrupted, followed by fast cooling.
- This disruption occurs first in the Western SPG.

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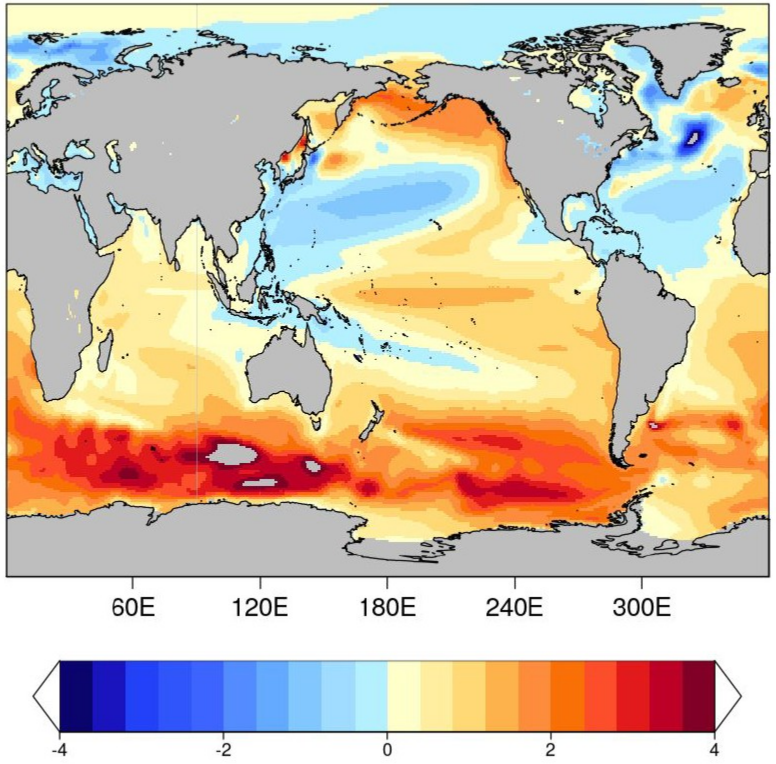
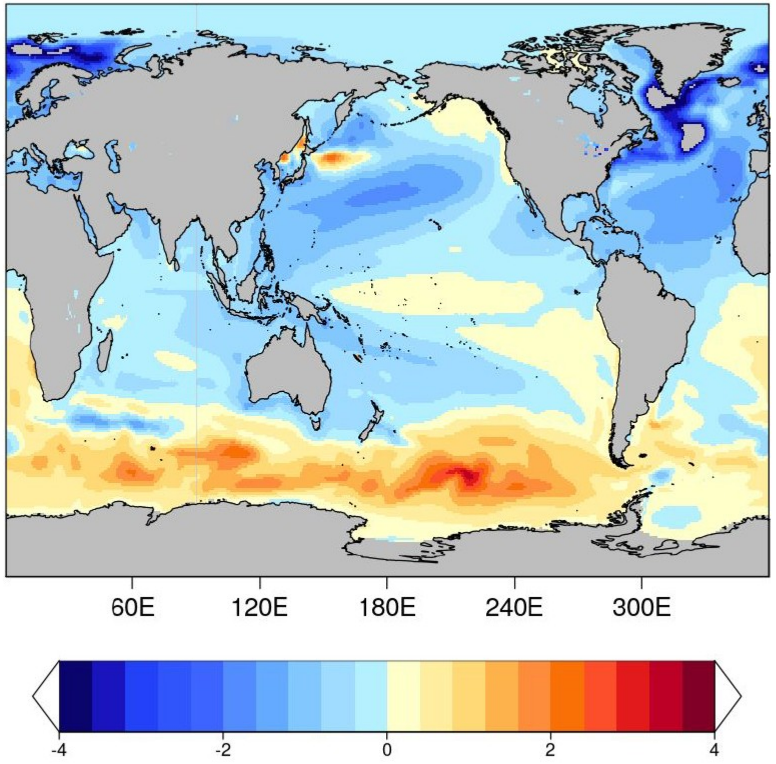
Global SST Drift

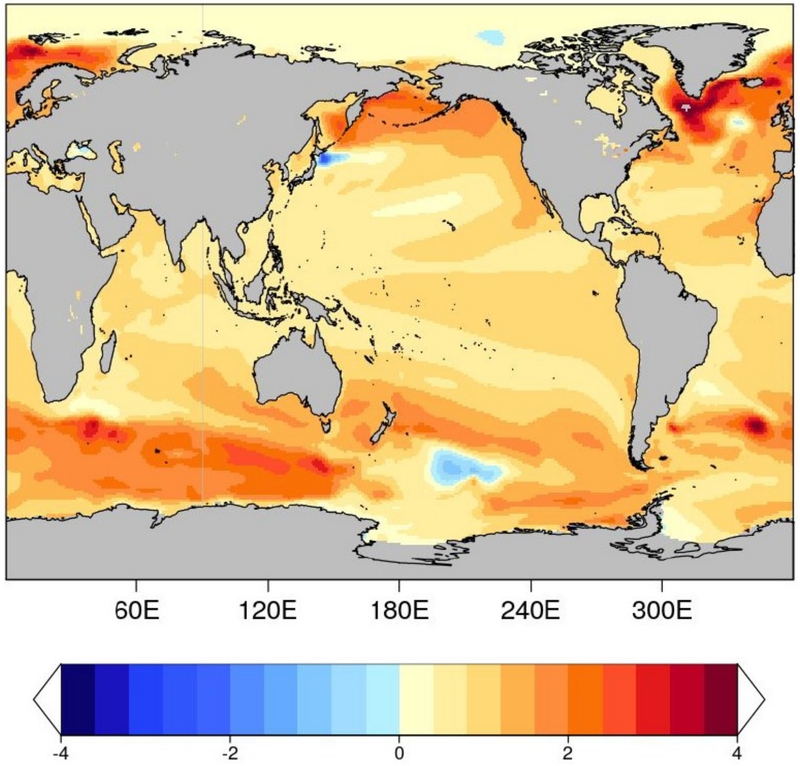
NoInit - Init (Year1)



Init (Year 10) - Init (Year1)



NoInit - Init (Year10)



Strong warm bias in Southern Ocean, cold bias in North Atlantic

North Atlantic cools further

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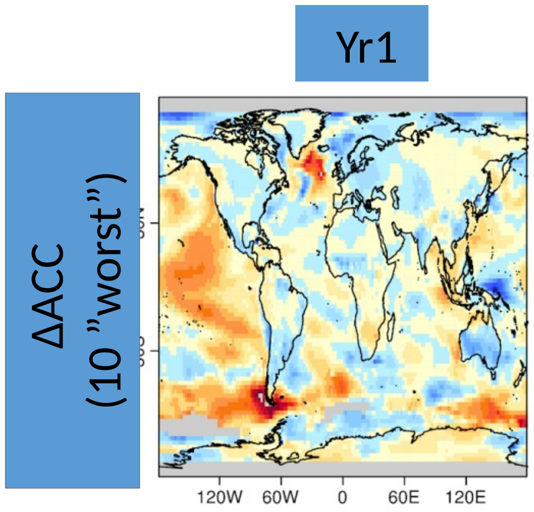
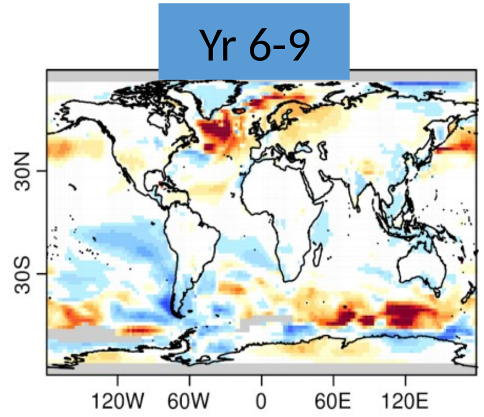
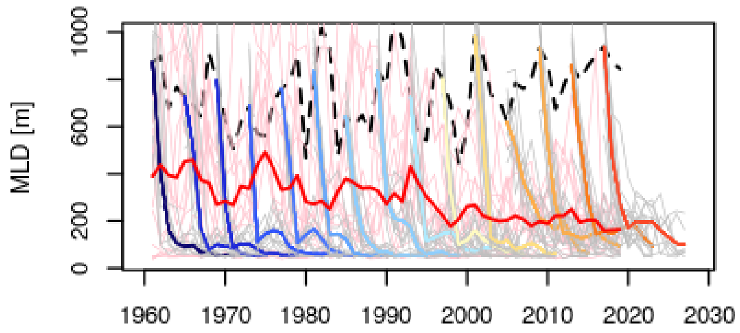
Summary

- Surface temperature skill in EC Earth 3 DCPP-A hindcasts:
  - initialization-related skill over some ocean regions in in forecast year 1
  - added value of initialization decreases beyond forecast year 1
  - higher skill of initialized runs over ENSO region in later forecast years
- Identifying added value from initialization is sensitive to the behaviour of non-initialized ensemble used for reference
- Initialization leads to smaller conditional bias over Pacific and greater conditional bias over North Atlantic
- Hindcasts do not appear to drift towards non-initialized ensemble in upper ocean in the North Atlantic







Thank You!

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This project received funding from the European Union's research and innovation programme under the Marie Skłodowska-Curie grant agreement no H2020-MSCA-COFUND-2016-75433 and has been supported by EU's Horizon 2020 project EUCP (EUropean Climate Prediction system) under grant agreement no. 776613.

STARS POST-DOCTORAL PROGRAM

ACTIONS

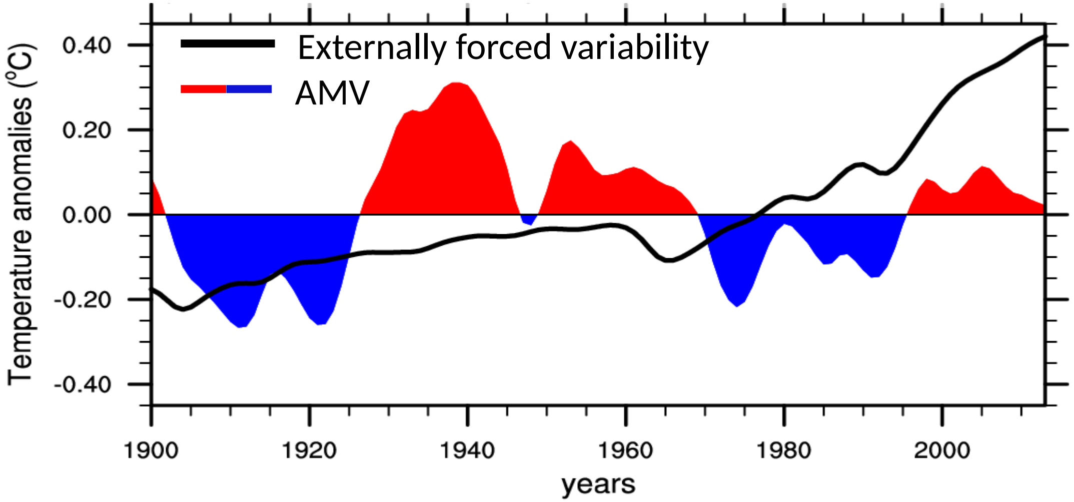
EUCP European Climate Prediction system

DCCP - C

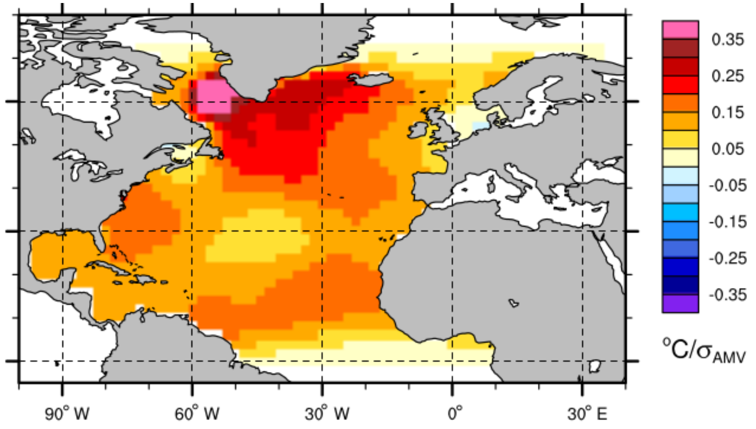
AMV impacts over Europe

- Model differences and similarities of AMV impacts on European climate
- How do pace maker experiments compare to free-running ones?

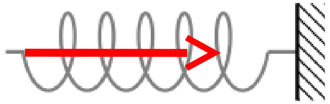
North Atlantic SST time series (Ting et al. 2009)



AMV pattern



(dataset: Ersst_v4)

Coupled model daily North Atlantic SST  Climatology **+/- AMV pattern**

Restoring (like a spring) of SST through non-solar surface fluxes :

$$Q_k = Q_k^o + \gamma(SST_k^o - SST_{AMV})$$

- Restoring coefficient of **γ = -40W/m^2/K** over North Atlantic (Eq-70°N)
- Free ocean-ice-land-atmosphere interactions outside of North Atlantic

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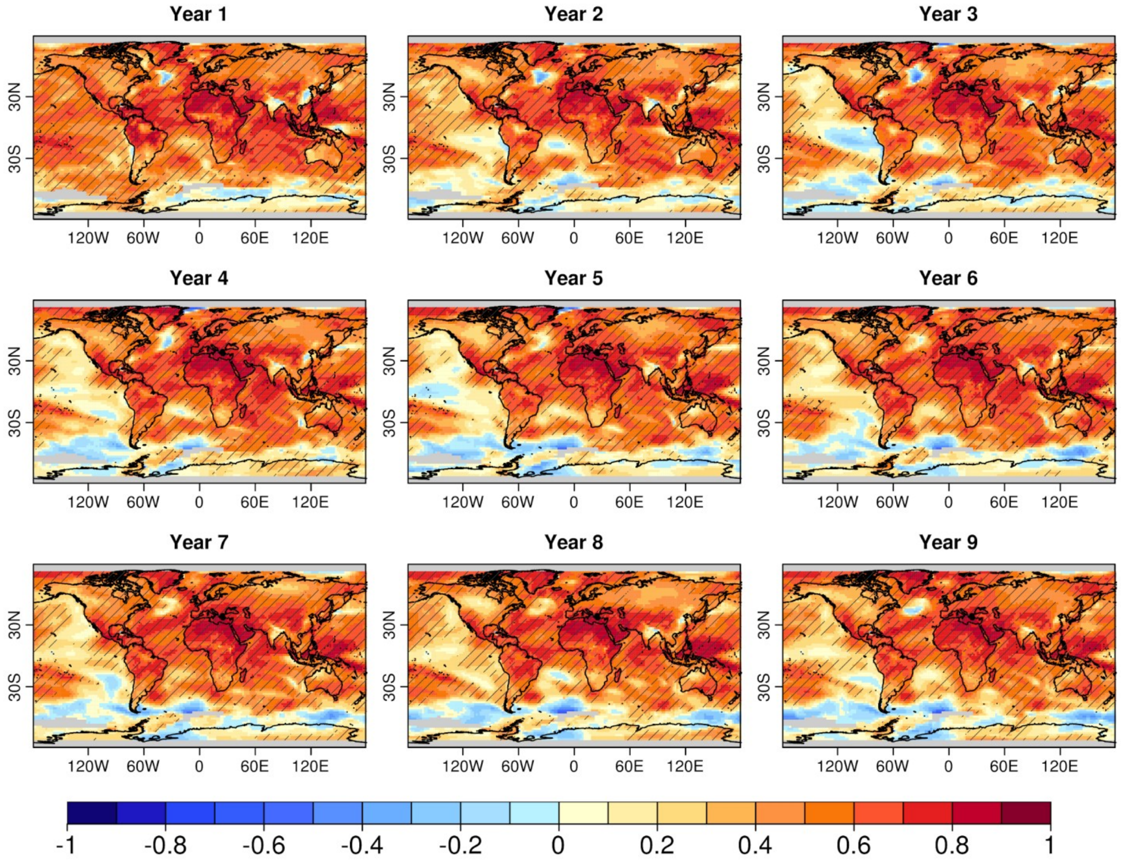
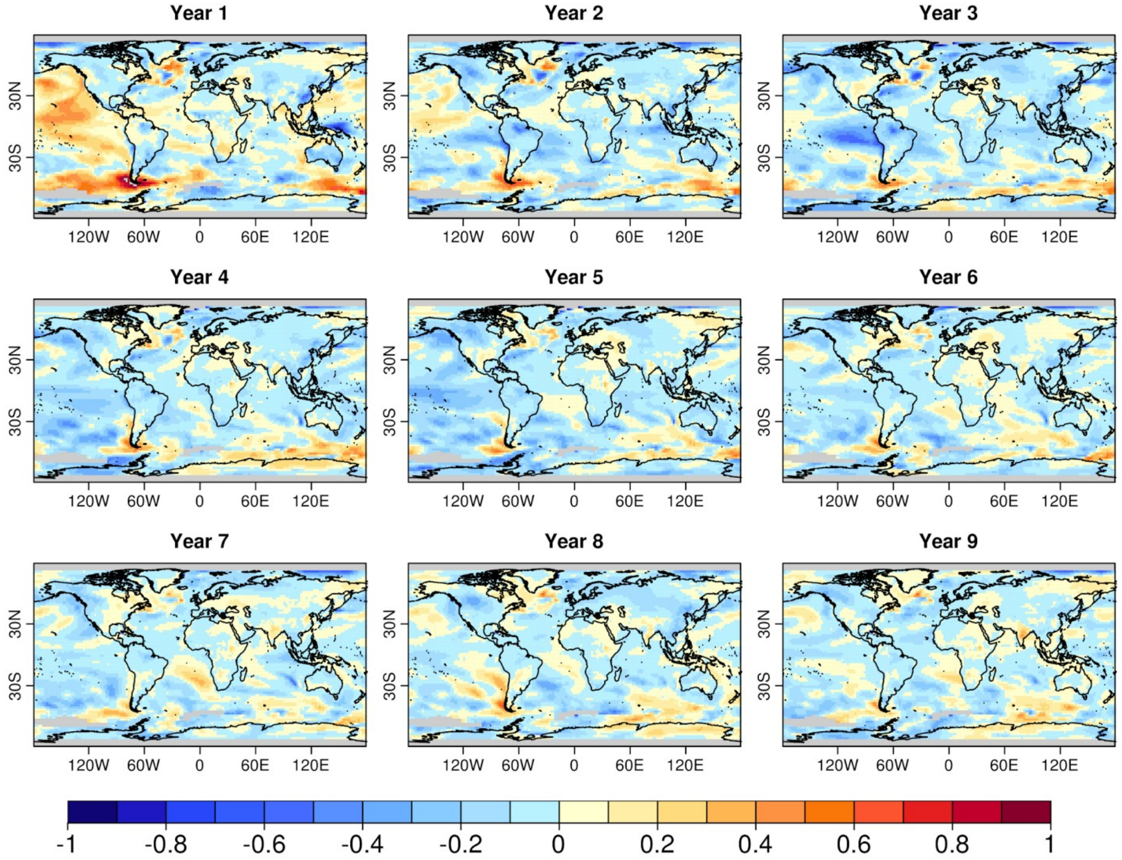
ACC for individual forecast years

ACC Init



Difference Init minus No-Init



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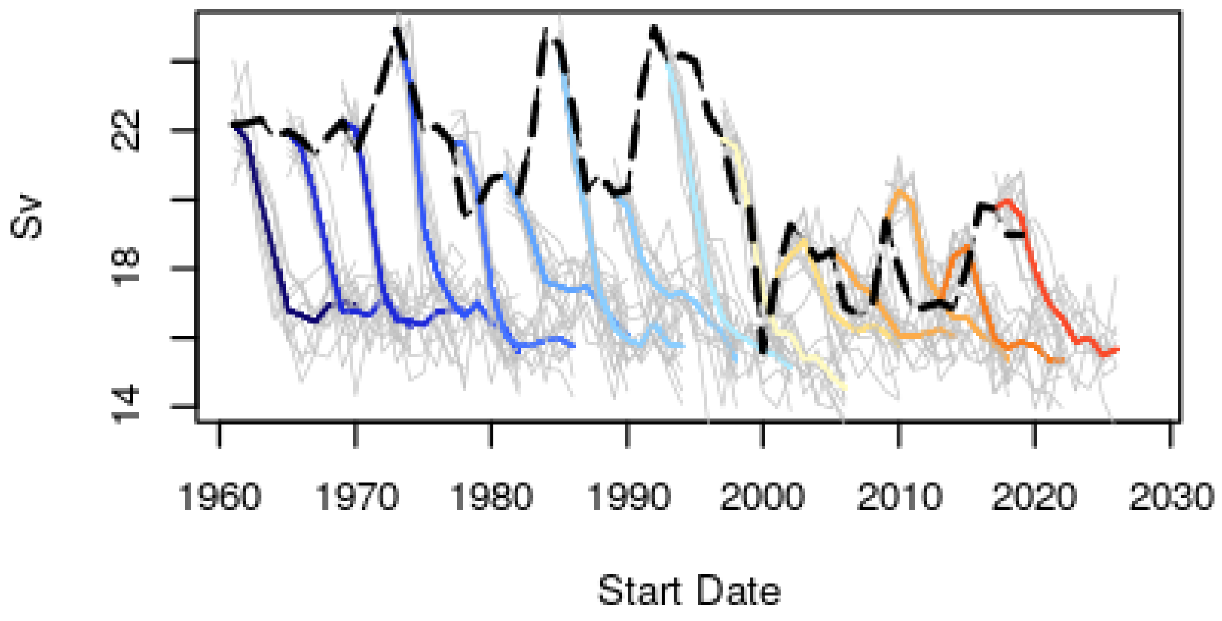
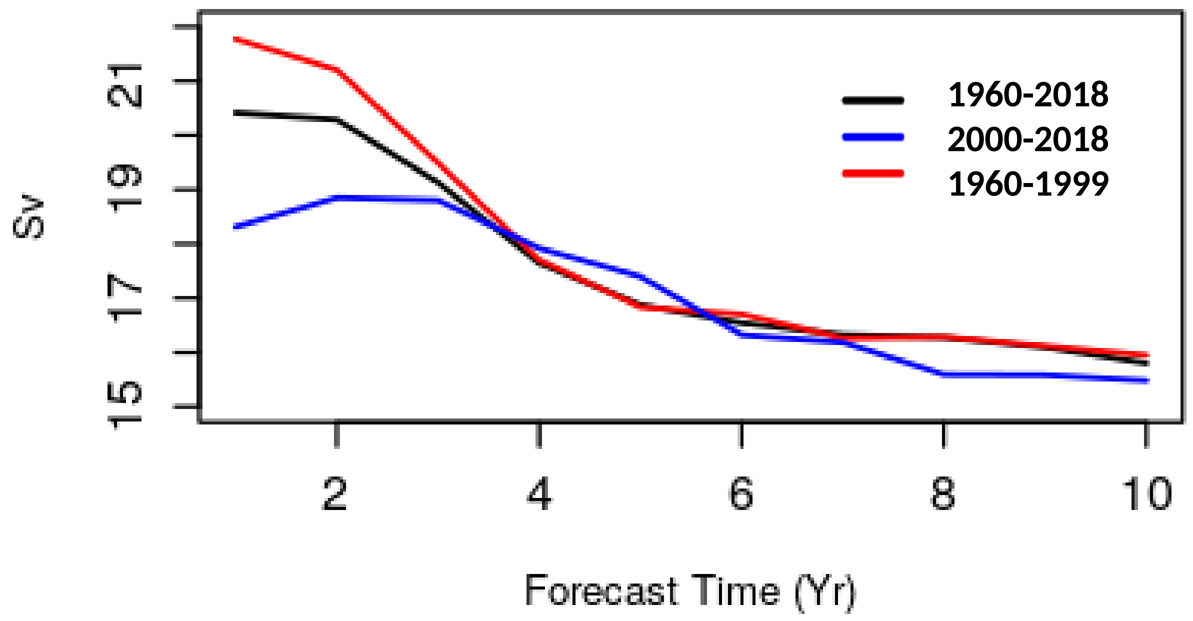
Model Drift in North Atlantic

AMOC at 45° N



AMOC at 45° N
Climatology for different start dates



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